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Climate impacts of the El Niño–Southern Oscillation on South America

Cai, Wenju; McPhaden, Michael J.; Grimm, Alice M.; Rodrigues, Regina R.; Taschetto, Andréa S; Garreaud, René D.; Dewitte, Boris; Poveda, Germán; Ham, Yoo-Geun; Santoso, Agus; Ng, Benjamin; Anderson, Weston; Wang, Guojian; Geng, Tao; Jo, Hyun-Su; Marengo, José A.; Alves, Lincoln M.; Osman, Marisol; Li, Shujun; Wu, Lixin; Karamperidou, Christina; **Takahashi, Ken**; Vera, Carolina (2020)
Nature Reviews Earth & Environment 1, 215–231
Doi: 10.1038/s43017-020-0040-3

Abstract
The climate of South America (SA) has long held an intimate connection with El Niño, historically describing anomalously warm sea-surface temperatures off the coastline of Peru. Indeed, throughout SA, precipitation and temperature exhibit a substantial, yet regionally diverse, relationship with the El Niño–Southern Oscillation (ENSO). For example, El Niño is typically accompanied by drought in the Amazon and north-eastern SA, but flooding in the tropical west coast and south-eastern SA, with marked socio-economic effects. In this Review, we synthesize the understanding of ENSO teleconnections to SA. Recent efforts have sought improved understanding of ocean–atmosphere processes that govern the impact, inter-event and decadal variability, and responses to anthropogenic warming. ENSO's impacts have been found to vary markedly, affected not only by ENSO diversity, but also by modes of variability within and outside of the Pacific. However, while the understanding of ENSO–SA relationships has improved, with implications for prediction and projection, uncertainty remains in regards to the robustness of the impacts, inter-basin climate interactions and interplay with greenhouse warming. A coordinated international effort is, therefore, needed to close the observational, theoretical and modelling gaps currently limiting progress, with specific efforts in extending palaeoclimate proxies further back in time, reducing systematic model errors and improving simulations of ENSO diversity and teleconnections.

Enlace repositorio SENAMHI: https://hdl.handle.net/20.500.12542/302
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Current thermal state of permafrost in the southern Peruvian Andes and potential impact from El Niño–Southern Oscillation (ENSO)

Yoshikawa, Kenji; Úbeda, Jose; Masías, Pablo; Vasquez, Pool; Ccallata, Beto; Concha, Ronald; Luna, Gonzalo; **Iparraguirre, Joshua; Ramos, Isabel; De la Cruz, Gustavo**; Cruz, Rolando; Pellitero, Ramón; Bonshoms, Martí (2020)
Permafrost and Periglac Process, 1– 12.
Doi: 10.1002/ppp.2064

Abstract
Tropical high-mountain permafrost has a unique thermal regime due to its exposure to strong solar radiation and to rough surface snow morphology, which reduce ground heat transfer from the surface. Latent heat transfer and higher albedo that occur during the snow-covered season contribute to positive feedback that supports the presence of permafrost. This preliminary study reports on the thermal state characteristics of tropical mountain permafrost in Peru. This work also evaluates the potential combined impact of the El Niño–Southern Oscillation (ENSO) in the mountain permafrost of the Coropuna and Chachani volcanic complexes, both located at the western edge of the southern Peruvian Altiplano. Temperature monitoring boreholes were established at 5,217 m at Coropuna and 5,331 m at Chachani, and electrical resistivity was surveyed in both sites. This 7-year discontinuous record of permafrost temperature data encompasses historically extreme El Niño/La Niña events. Our results show that the current lower-altitude permafrost boundary (~5,100 m a.s.l.) is critically influenced by the balance of wet and dry seasons: permafrost tends to deplete during drought years. Typical permafrost thickness was 10–20 m and contained ice-rich pore spaces. The presence of permafrost and its thermal resistance depends on ice content and on higher albedo, usually due to: (a) hydrothermal alteration, which transforms the volcanic rocks into surfaces with ideal albedo for permafrost resilience; and (b) sublimation of the snow cover, forming ice-pinnacles named penitents.
Enlace repositorio SENAMHI: https://hdl.handle.net/20.500.12542/429

Assessment of ECMWF SEAS5 seasonal forecast performance over South America

Gubler, S.; Sedlmeier, K.; Bhend, J.; **Ávalos, G.**; Coelho, C.A.S.; **Escajadillo, Y.**; Jacques-Coper, M.; Martinez, R.; Schwierz, C.; De Skansi, M.; Spirig, C. (2020)
Wea. Forecasting 35(2), 561–584.
Doi: 10.1175/WAF-D-19-0106.1

Acceso Abierto

Abstract
Seasonal predictions have a great socioeconomic potential if they are reliable and skillful. In this study, we assess the prediction performance of SEAS5, version 5 of the seasonal prediction system of the European Centre for Medium-Range Weather Forecasts (ECMWF), over South America against homogenized station data. For temperature, we find the highest prediction performances in the tropics during austral summer, where the probability that the predictions correctly discriminate different observed outcomes is 70%. In regions lying to the east of the Andes, the predictions of maximum and minimum temperature still exhibit considerable performance, while farther to the south in Chile and Argentina the temperature prediction performance is low. Generally, the prediction performance of minimum temperature is slightly lower than for maximum temperature. The prediction performance of precipitation is generally lower and spatially and temporally more variable than for temperature. The highest prediction performance is observed at the coast and over the highlands of Colombia and Ecuador, over the northeastern part of Brazil, and over an isolated region to the north of Uruguay during DJF. In general, Niño-3.4 has a strong influence on both air temperature and precipitation in the regions where ECMWF SEAS5 shows high performance, in some regions through teleconnections (e.g., to the north of Uruguay). However, we show that SEAS5 outperforms a simple empirical prediction based on Niño-3.4 in most regions where the prediction performance of the dynamical model is high, thereby supporting the potential benefit of using a dynamical model instead of statistical relationships for predictions at the seasonal scale.

Enlace del repositorio SENAMHI: https://hdl.handle.net/20.500.12542/424

Climate diagnostics of the extreme floods in Peru during early 2017

Son, R.; Wang, S.-Y.S.; Tseng, W.-L.; **Barreto Schuler, Christian**; Becker, E.; Yoon, J.-H. (2020). *Climatec Dynamic* 54, 935–945.
Doi:10.1007/s00382-019-05038-y

Acceso Abierto

Abstract
From January through March 2017, a series of extreme precipitation events occurred in coastal Peru, causing severe floods with hundreds of human casualties and billions of dollars in economic losses. The extreme precipitation was a result of unusually strong recurrent patterns of atmospheric and oceanic conditions, including extremely warm coastal sea surface temperatures (SST) and weakened trade winds. These climatic features and their causal relationship with the Peruvian precipitation were examined. Diagnostic analysis and model experiments suggest that an atmospheric forcing in early 2017, which was moderately linked to the Trans-Niño Index (TNI), initiated the local SST warming along coastal Peru that later expanded to the equator. In January 2017, soil moisture was increased by an unusual expansion of Amazonian rainfall. By March, localized and robust SST warming provided positive feedback to the weakening of the trade winds, leading to increased onshore wind and a subsequent enhancement in rainfall. The analysis points to a tendency towards more frequent and stronger variations in the water vapor flux convergence along the equator, which is associated with the increased precipitation in coastal Peru.

Enlace del repositorio SENAMHI: https://hdl.handle.net/20.500.12542/287

Control of seasonal and inter-annual rainfall distribution on the Strontium-Neodymium isotopic compositions of suspended particulate matter and implications for tracing ENSO events in the Pacific coast (Tumbes basin, Peru)

Moquet, Jean -Sébastien; Morera, Sergio; Turcq, Bruno; Poitrasson, Franck; Roddaz, Martin; Moreira- Turcq, Patricia; Carlo Espinoza, Jhan; Guyot, Jean-Loup; **Takahashi, Ken**; Orrillo-Vigo, Jhon; Petrick, Susana; Mounic, Stéphanie; Sondag, Francis (2020).
Global and Planetary Change, 185, 103080.
Doi: 10.1016/j.gloplacha.2019.103080

Abstract
The geochemistry of riverine sediments exported to the oceans is important for paleo-hydro-climatic reconstruction. However, climate reconstruction requires a good understanding of the relationship between geochemistry and hydrological variability and sediment sources. In this study, we analyzed the major elements, the strontium-neodymium radiogenic isotopes signatures (87Sr/86Sr and εNd) and the mineralogy of the suspended particulate matter (SPM) sampled monthly during two hydrologic years (2007–2008, a wet year, and 2010–2011, a normal hydrological year) upstream the Tumbes River outlet. The hydroclimate of this Ecuador-Peru binational basin is particularly sensitive to ENSO (El Niño Southern Oscillation) event While mineralogy (dominated by illite) and the chemical alteration index (from 75 to 82) remain almost constant along the two hydrological years, 87Sr/86Sr (0.7115 to 0.7176) and εNd (−7.8 to −1.9) signatures are particularly sensitive to discharge and SPM concentration variations. Along the hydrological year, two sources control the εNd variability: (1) volcanic rocks, which dominate during the dry season, and (2) plutonic/metamorphic sources, whose contribution increases during the wet season. This behavior is confirmed by the correlation between εNd signature and the monthly rainfall contribution from volcanic area (R = 0.58; p-value < 0.01), and also with the daily discharge at the outlet (R = -0.73; p-value < 0.01). For most of the samples, 87Sr/86Sr is less variable along the hydrological year. However, two exceptional high discharge and SPM concentration conditions sampled exhibit more radiogenic (higher) 87Sr/86Sr signatures when plutonic/metamorphic rocks derived sediments are released in sufficient quantities to notably change the SPM isotopic Sr value of the Tumbes River. Hence, this study demonstrates that 87Sr/86Sr and εNd signatures can be used as powerful proxies for paleoclimate reconstructions based on sediment core's analysis in relation with spatial rainfall distribution and intensity in Pacific sedimentary basins submitted to the diversity of ENSO events.

Enlace de repositorio SENAMHI: https://hdl.handle.net/20.500.12542/258

Observed and projected hydroclimate changes in the Andes

Pabón-Caicedo, JD; Arias, PA; Carril, AF; Espinoza JC; Borrel LF; Goubanova K; **Lavado-Casimiro W**; Masiokas M; Solman S; Villalba, R. (2020)
Frontiers in Earth Science 8(61), 1-29.
Doi: 10.3389/feart.2020.00061

Acceso Abierto

Abstract
The Andes is the most biodiverse region across the globe. In addition, some of the largest urban areas in South America are located within this region. Therefore, ecosystems and human population are affected by hydroclimate changes reported at global, regional and local scales. This paper summarizes progress of knowledge about long-term trends observed during the last two millennia over the entire Andes, with more detail for the period since the second half of the 20th century, and presents a synthesis of climate change projections by the end of the 21st century. In particular, this paper focuses on temperature, precipitation and surface runoff in the Andes. Changes in the Andean cryosphere are not included here since this particular topic is discussed in other paper in this Frontiers special issue, and elsewhere (e.g. IPCC, 2019b). While previous works have reviewed the hydroclimate of South America and particular sectors (i.e., Amazon and La Plata basins, the Altiplano, Northern South America, etc.) this review includes for the first time the entire Andes region, considering all latitudinal ranges: tropical (North of 27 S), subtropical (27 S□37 S) and extratropical (South of 37 S). This paper provides a comprehensive view of past and recent changes, as well as available climate change projections, over the entire Andean range. From this review, the main knowledge gaps are highlighted and urgent research necessities in order to provide more mechanistic understanding of hydroclimate changes in the Andes and more confident projections of its possible changes in association with global climate change.

Enlace Repositorio SENAMHI: https://hdl.handle.net/20.500.12542/331

Precipitation diurnal cycle assessment of satellite-based estimates over Brazil

Afonso, J.M.S.; Vila, D.A.; Gan, M.A.; Quispe, D.P.; Barreto, N.J.C.; **Chinchay, J.H.H**.; Palharini, R.S.A. (2020)
Remote Sens. 2020, 12(14), 2339
Doi: 10.3390/rs12142339

Acceso Abierto

Abstract
The main objective of this study is to assess the ability of several high-resolution satellite-based precipitation estimates to represent the Precipitation Diurnal Cycle (PDC) over Brazil during the 2014–2018 period, after the launch of the Global Precipitation Measurement satellite (GPM). The selected algorithms are the Global Satellite Mapping of Precipitation (GSMaP), The Integrated Multi-satellitE Retrievals for GPM (IMERG) and Climate Prediction Center (CPC) MORPHing technique (CMORPH). Hourly rain gauge data from different national and regional networks were used as the reference dataset after going through rigid quality control tests. All datasets were interpolated to a common 0.1° × 0.1° grid every 3 h for comparison. After a hierarchical cluster analysis, seven regions with different PDC characteristics (amplitude and phase) were selected for this study. The main results of this research could be summarized as follow: (i) Those regions where thermal heating produce deep convective clouds, the PDC is better represented by all algorithms (in term of amplitude and phase) than those regions driven by shallow convection or low-level circulation; (ii) the GSMaP suite (GSMaP-Gauge (G) and GSMaP-Motion Vector Kalman (MVK)), in general terms, outperforms the rest of the algorithms with lower bias and less dispersion. In this case, the gauge-adjusted version improves the satellite-only retrievals of the same algorithm suggesting that daily gauge-analysis is useful to reduce the bias in a sub-daily scale; (iii) IMERG suite (IMERG-Late (L) and IMERG-Final (F)) overestimates rainfall for almost all times and all the regions, while the satellite-only version provide better results than the final version; (iv) CMORPH has the better performance for a transitional regime between a coastal land-sea breeze and a continental amazonian regime. Further research should be performed to understand how shallow clouds processes and convective/stratiform classification is performed in each algorithm to improve the representativity of diurnal cycle

Enlace Repositorio SENAMHI: https://hdl.handle.net/20.500.12542/466

Artículos científicos

Trends and variability of precipitation extremes in the Peruvian Altiplano (1971–2013)

Huerta, Adrian.; Lavado-Casimiro, W. (2020).
International Journal of Climatology,
Doi: 10.1002/joc.6635

Abstract
Precipitation extremes have been investigated throughout the last decades in different regions of the Andes. However, little attention has been paid to the Altiplano region (Central Andes), especially to the Peruvian Altiplano (PA) that represents a complex area and is highly vulnerable to extreme events, such as floods and droughts, driven by the strong variability of precipitation. This study focuses on the analysis of 11 extreme precipitation indices (EPIs) in the period 1971–2013. In this context, commonly used statistical trend and break analyses were applied and a false discovery procedure was used in order to reduce the number of artificial significant tests. Additionally, the relative dominance of precipitation frequency and intensity in interannual precipitation datasets was determined. Finally, the correlation between EPIs and six oceanic-atmospheric indices were analysed. The results indicate that there is no significant global trend towards wet or dry conditions in the PA, although a signal of a more slightly decrease of precipitation is presented in the Southern PA. Additionally, interannual variability of total precipitation is mainly dominated by precipitation frequency. The Central Tropical Pacific sea surface temperature plays a major role for the maximum and average length of wet periods as well as for total precipitation. This finding is particularly relevant for the southwestern PA. Our results have important implications for risk management and adaptation planning related to extreme hydrological events in the PA.

Enlace Repositorio SENAMHI: https://hdl.handle.net/20.500.12542/427

Dry season circulation-type classification applied to precipitation and temperature in the Peruvian Andes

Bonshoms, Martí; Álvarez-Garcia, Francisco J.; Ubeda, Jose; Cabos, William; **Quispe, Kelita**; Liguori, Giovanni. (2020).
International Journal Climatology,
Doi: 10.1002/joc.6593.

Abstract
We present the first systematic classification of circulation regimes that characterize the Tropical Andes during the dry season (May–August). We apply the hierarchical k-means clustering method to ERA-Interim reanalysis data of daily mean geopotential height at 500- and 200-hPa levels for the period 1981–2015. Specifically, by combining the variability in intensity and location of geopotential anomalies we identify 12 circulation types (CTs). We then establish the relationship between the CTs and surface conditions in the Peruvian Andes (PA) analysing high-resolution gridded datasets of daily mean temperature and rainfall. Our results indicate that intense precipitations and low minimum temperatures are often associated with an Upper Tropospheric Trough (UTT) centred at subtropical latitudes (~30°S) and between 80° and 70°W of longitude. Moreover, drier and warmer conditions across the entire PA region are largely associated with three anticyclonic CTs. Strong negative anomalies in daily maximum (minimum) temperatures can be related to the effect of day (night) cloudiness in the radiative balance, but also to subtropical cold air advections favoured by the UTT. While CTs featuring warmer (colder) conditions have become more (less) frequent in the last decades of the record, there is no systematic link between positive or negative trends in occurrence and the wetter and drier character of the CTs. The annual frequencies of 10 CTs are significantly correlated with El Niño-Southern Oscillation, with warmer and drier (cooler and wetter) CTs generally preceded by an El Niño (La Niña) in the previous wet season.

Enlace Repositorio SENAMHI: https://hdl.handle.net/20.500.12542/428

Artículos científicos

AGOSTO 2020

Construction of a high-resolution gridded rainfall dataset for Peru from 1981 to the present day

Aybar, César; Fernández, C.; Huerta, A.; Lavado-Casimiro, W.; Vega, Fiorela; Felipe-Obando, O. (2020).

Hydrological Sciences Journal 65 (5), 770-785.
Doi: 10.1080/02626667.2019.1649411

Abstract
A new gridded rainfall dataset available for Peru is introduced, called PISCOp V2.1 (Peruvian Interpolated data of SENAMHI's Climatological and Hydrological Observations). PISCOp has been developed for the period 1981 to the present, with an average latency of eight weeks at 0.1° spatial resolution. The merging algorithm is based on geostatistical and deterministic interpolation methods including three different rainfall sources: (i) the national quality-controlled and infilled raingauge dataset, (ii) radar-gauge merged precipitation climatologies and (iii) the Climate Hazards Group Infrared Precipitation (CHIRP) estimates. The validation results suggest that precipitation estimates are acceptable showing the highest performance for the Pacific coast and the western flank of the Andes. Furthermore, a meticulous quality-control and gap-infilling procedure allowed us to reduce the formation of inhomogeneities (non-climatic breaks). The dataset is publicly available at https://piscoprec.github.io/ and is intended to support hydrological studies and water management practices

Enlace Repositorio SENAMHI: https://hdl.handle.net/20.500.12542/426

A combined view on precipitation and temperature climatology and trends in the southern Andes of Peru

Imfeld, Noemi; Sedlmeier, Katrin; Gubler, Stefanie; **Correa Marrou, Kris; Davila, Cristina P.; Huerta, Adrian; Lavado-Casimiro, Waldo**; Rohrer, Mario; Scherrer, Simon C.; Schwierz, Cornelia (2020)
International Journal Climatology, 1-20.
Doi: 10.1002/joc.6645

Acceso Abierto

Abstract
In the southern Peruvian Andes, communities are highly dependent on climatic conditions due to the mainly rain-fed agriculture and the importance of glaciers and snow melt as a freshwater resource. Longer-term trends and year-to-year variability of precipitation or temperature severely affect living conditions. This study evaluates seasonal precipitation and temperature climatologies and trends in the period 1965/66–2017/18 for the southern Peruvian Andes using quality-controlled and homogenized station data and new observational gridded data. In this region, precipitation exhibits a strong annual cycle with very dry winter months and most of the precipitation falling from spring to autumn. Spatially, a northeast–southwest gradient in austral spring is observed, related to an earlier start of the rainy season in the northeastern part of the study area. Seasonal variations of maximum temperature are weak with an annual maximum in austral spring, which is related to reduced cloud cover in austral spring compared to summer. On the contrary, minimum temperatures show larger seasonal variations, possibly enhanced through changes in longwave incoming radiation following the precipitation cycle. Precipitation trends since 1965 exhibit low spatial consistency except for austral summer, when in most of the study area increasing precipitation is observed, and in austral spring, when stations in the central-western region of the study area register decreasing precipitation. All seasonal and annual trends in maximum temperature are larger than trends in minimum temperature. Maximum temperature exhibits strong trends in austral winter and spring, whereas minimum temperature trends are strongest in austral winter. We hypothesize, that these trends are related to precipitation changes, as decreasing (increasing) precipitation in spring (summer) may enhance maximum (minimum) temperature trends through changes in cloud cover. El Niño Southern Oscillation (ENSO), however, has modifying effects onto precipitation and temperature, and thereby leads to larger trends in maximum temperatures.

Enlace Repositorio SENAMHI: https://hdl.handle.net/20.500.12542/425

Towards more resilient food systems for smallholder farmers in the peruvian altiplano: The potential of community-based climate services

Rossa, A.; Flubacher, M.; **Cristobal, L.**; **Ramos, H.**; Lechthaler, F. (2020)

In: Leal Filho W., Jacob D. (eds) Handbook of Climate Services. Climate Change Management. Springer.
Doi: 10.1007/978-3-030-36875-3_17

Abstract

Experiences from the disastrous 2016 El Niño revealed that its forecast, although available, was not known, accessed or understood by a large part of agricultural communities living in remote rural areas. This is all the more striking since these population groups are particularly vulnerable to adverse climate events as their livelihoods heavily depend on climate-sensitive agricultural production. In the framework of Climandes, a twinning project between the meteorological services of Peru and Switzerland, we implemented and evaluated the impact of community-based climate services that were co-developed with the target smallholder communities of the semi-arid highlands of the southern Peruvian Andes, where small-scale farmers are especially exposed to adverse climate events due to high inter-annual climate variability and weak socio-economic capacities. In this chapter we analyse the project implementation through a socio-economic lens. Research results generated alongside the project indicate that the well-directed user engagement resulted in a strong increase of trust in the weather service SENAMHI Peru and led to improved consideration of the information provided in the respective decision-making processes. We highlight the key steps that proved to be indispensable for the implementation of meaningful and sustainable climate services. The project outcomes point to the great and widely untapped potential of community-based climate services to reduce vulnerability and strengthen resilience of smallholder farmers in the face of changing climate conditions.

Enlace Repositorio SENAMHI: https://hdl.handle.net/20.500.12542/395

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