Hydrology and Water Resources

B-EPICC's hydrology portfolio focuses on the water-food-energy nexus under climate conditions, seeking to work with local stakeholders on modeling and policy development

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PIK
Potsdam Institute for Climate Impact Research

B-EPICC
Brazil East Africa Peru India Climate Capacities

Supported by:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
based on a decision of the German Bundestag

IKI Internationale Klimaschutz Initiative

São José dos Campos 2022

Hydrology WP - Peru

Our main research objective in Peru is to understand the distribution of water budget components at national scale of Peru and its sensitivity to climate change for better water resources management

NEW GRIDDED PRECIPITATION DATA FOR PERU

To collect or generate reliable and accurate hydrometeorological dataset, particularly precipitation (Manuscript published in Journal of hydrometeorology)

ANALYSIS OF THE DISTRIBUTION OF WATER BUDGET COMPONENTS IN PERUVIAN BASINS

To understand the hydrological processes of Andean-Amazon basins (Manuscript published Hydrological Sciences Journal)

PROJECTED CHANGES IN WATER BUDGET COMPONENTS

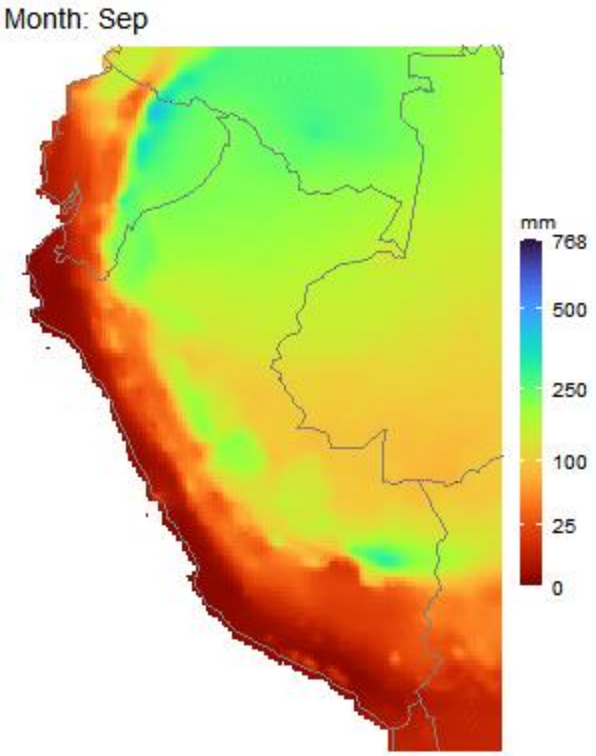
To assess the climate change impact on water resources in Peruvian river basins (Manuscript in preparation)

Generation of a Gridded Precipitation Product for Peru and Ecuador (RAIN4PE) and Application in the Hydrological Modeling of Peruvian Catchments including the Upper Amazon River Basin

Carlos Antonio Fernandez-Palomino (palomino@pik-potsdam.de, cafpxl@gmail.com)[1,2], Fred F. Hattermann[1], Valentina Krysanova[1], Anastasia Lobanova[1], Fiorella Vega-Jácome[3], Waldo Lavado[3], William Santini[4], Cesar Aybar[5], and Axel Bronstert[2]

[1] Potsdam Institute for Climate Impact Research, [2] University of Potsdam, [3] Servicio Nacional de Meteorología e Hidrología del Perú, [4] Institut de Recherche pour le Développement, [5] University of Salzburg

RAIN4PE (Rain for Peru and Ecuador) is the only gridded precipitation dataset for Peru and Ecuador that benefits from observed precipitation, estimated precipitation (satellite and re-analysis) and elevation data, and is supplemented by streamflow data to estimate total precipitation in basins with important contribution of cloud/fog water. RAIN4PE is available at daily resolution and ~10 km for the period 1981-2015



POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

PIK

B-EPICC

BRAZIL EAST AFRICA PERU INDIA CLIMATE CAPACITIES

Lima 2022

Objectives

1) to generate a high-spatial-resolution and hydrologically adjusted precipitation dataset called **RAIN4PE** (Rain for Peru and Ecuador), and

2) to evaluate the applicability of **RAIN4PE** and the current state-of-the-art precipitation products (**ERA5, CHIRP, CHIRPS, MSWEP, and PISCO**) for hydrological modeling of Peruvian and Ecuadorian watersheds.

Overview: precipitation measurement and precipitation datasets


AGU PUBLICATIONS

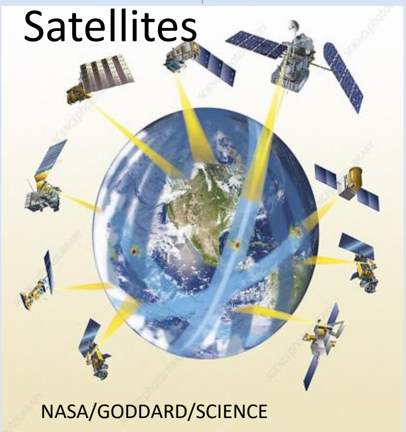
Reviews of Geophysics

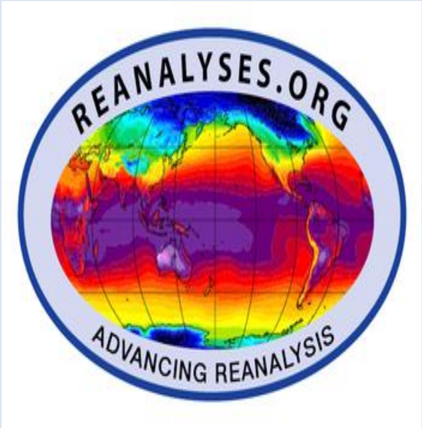
REVIEW ARTICLE

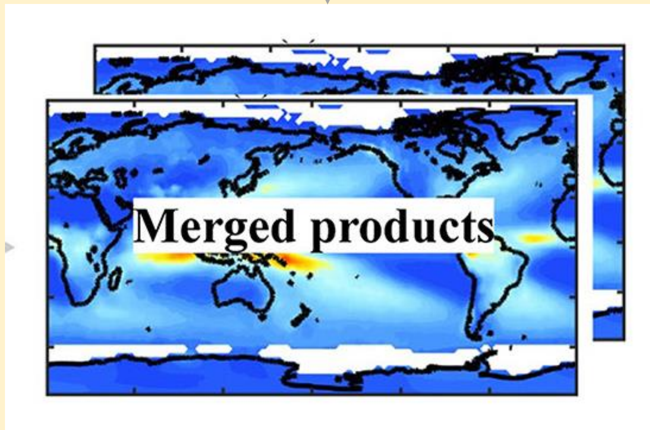
10.1002/2017RG000574

A Review of Global Precipitation Data Sets: Data Sources, Estimation, and Intercomparisons

Qiaohong Sun[1], Chiyuan Miao[1], Qingyun Duan[1], Hamed Ashouri[2], Soroosh Sorooshian[2], and Kuo-Lin Hsu[2]







- CRU (Harris et al. 2014)
- GPCC (Rudolf et al. 2009)
- HYBAM (Guimberteau et al. 2012)

Gauge-based P datasets

- **CHIRP** (Funk et al. 2015)
- CMORPH (Joyce et al. 2004)
- TMPA (Huffman et al. 2007)
- IMERG (Huffman et al. 2019)

- ERA-Interim (Dee et al. 2011)
- MERRA (Reichle et al. 2017)
- **ERA5** (Hersbach et al. 2020)

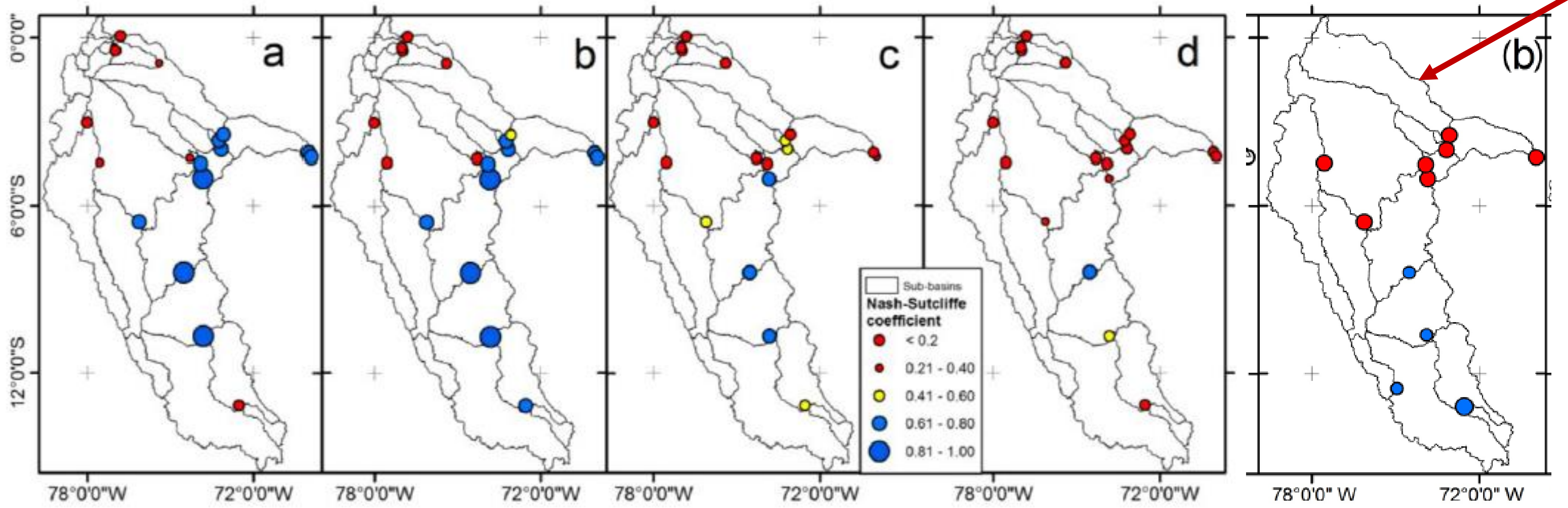
Non-gauge corrected P datasets

- **CHIRPS** (Funk et al. 2015a)
- **MSWEP** (Beck et al. 2019b, 2017)
- **PISCO-prec** (Aybar et al. 2020)
- **RAIN4PE** (Fernandez et al. 2022)

Gauge-corrected P datasets

Motivation: Poor performance of hydrological model using different precipitation (P) datasets in the upper Amazon River Basin

Gauge-based P	Uncorrected (satellite-based) P			
HYBAM	TMPA	CMORPH	PERSIANN	IMERG



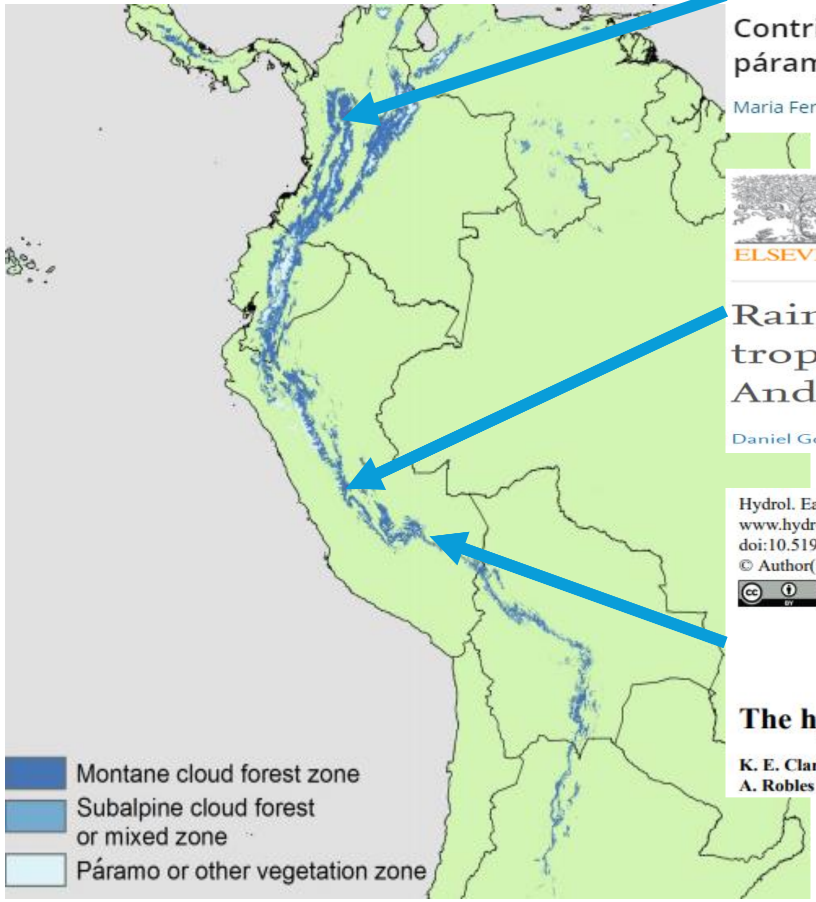
Zubieta et al. 2015

Zubieta et al. 2017

Zubieta, R., A. Getirana, J. C. Espinoza, and W. Lavado, 2015: Impacts of satellite-based precipitation datasets on rainfall–runoff modeling of the Western Amazon basin of Peru and Ecuador. J. Hydrol., 528, 599–612, https://doi.org/10.1016/j.jhydrol.2015.06.064.
——, ——, ——, W. Lavado-Casimiro, and L. Aragon, 2017: Hydrological modeling of the Peruvian–Ecuadorian Amazon Basin using GPM-IMERG satellite-based precipitation dataset. Hydrol. Earth Syst. Sci., 21, 3543–3555, https://doi.org/10.5194/hess-21-3543-2017.

Consideration : importance of cloud/fog water input into the system in the generation of precipitation dataset

Contribution of cloud/fog water into the system



Helmer et al. 2019

Hydrological Processes

RESEARCH ARTICLE

Contribution of occult precipitation to the water balance of páramo ecosystems in the Colombian Andes

Maria Fernanda Cárdenas, Conrado Tobón, Wouter Buytaert

ELSEVIER

Forest Ecology and Management

Volume 255, Issues 3–4, 20 March 2008, Pages 1315-1325

Rainfall and cloud-water interception in tropical montane forests in the eastern Andes of Central Peru

Daniel Gomez-Peralta [a], Steven F. Oberbauer [a, b], Michael E. McClain [c], Thomas E. Philippi [a]

Hydrol. Earth Syst. Sci., 18, 5377–5397, 2014
www.hydrol-earth-syst-sci.net/18/5377/2014/
doi:10.5194/hess-18-5377-2014
© Author(s) 2014. CC Attribution 3.0 License.

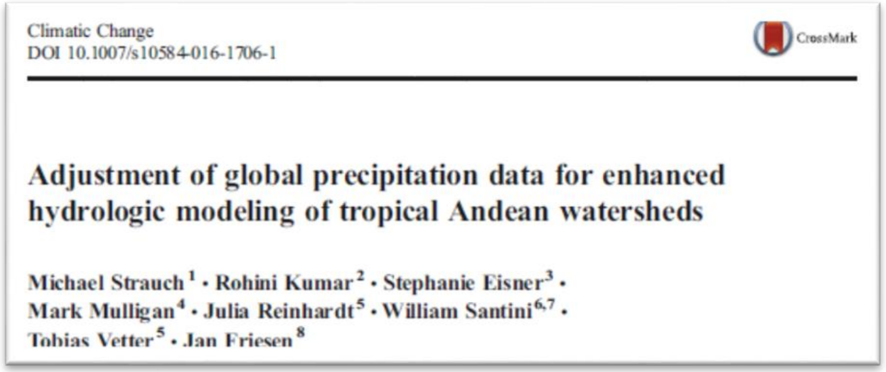
Hydrology and Earth System Sciences

The hydrological regime of a forested tropical Andean catchment

K. E. Clark[1,*], M. A. Torres[2], A. J. West[2], R. G. Hilton[3], M. New[1,4], A. B. Horwath[5], J. B. Fisher[6], J. M. Rapp[7,**], A. Robles Caceres[8], and Y. Malhi[1]

- 0-30% of total precipitation (Liquid precipitation + cloud/fog water)

Hydrological implications when cloud water is misrepresented in precipitation products in the upper Amazon River basin


Climatic Change
DOI 10.1007/s10584-016-1706-1

Adjustment of global precipitation data for enhanced hydrologic modeling of tropical Andean watersheds

Michael Strauch[1] • Rohini Kumar[2] • Stephanie Eisner[3] • Mark Mulligan[4] • Julia Reinhardt[5] • William Santini[6,7] • Tobias Vetter[5] • Jan Friesen[8]

- Runoff ratio greater than 1
- water budget imbalance

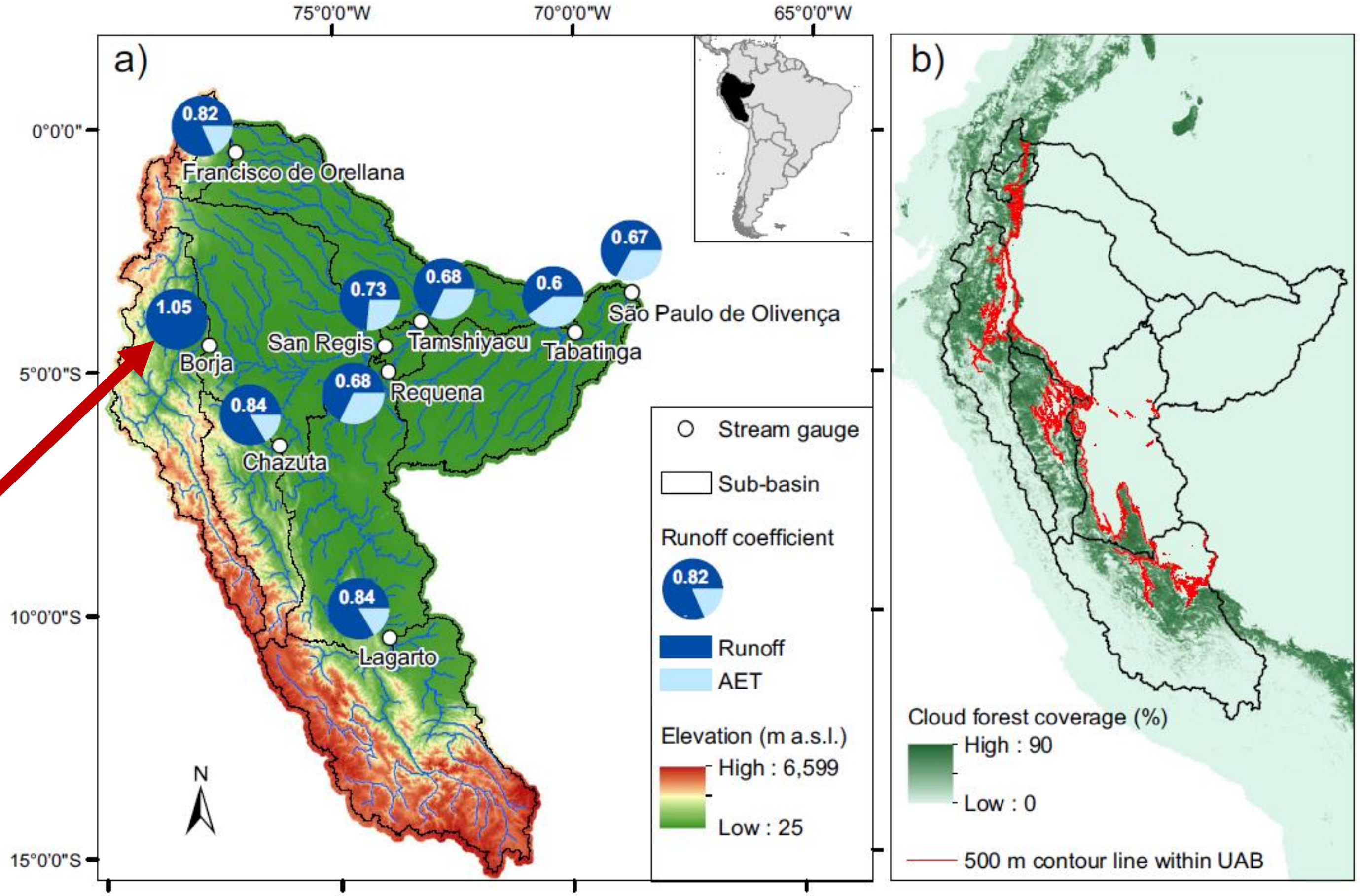


Fig. 1 **a** Elevation map of the UAB including stream gauges and their runoff coefficients based on WFDEI precipitation and observed runoff (AET = actual evapotranspiration after water balance closure); **b** distribution of significantly cloud affected forests (source: Mulligan 2010)

How to estimate total precipitation in regions with scarce data and water budget imbalance?

JGR Atmospheres

Research Article | Free Access

Soil as a natural rain gauge: Estimating global rainfall from satellite soil moisture data

Luca Brocca, Luca Ciabatta, Christian Massari, Tommaso Moramarco, Sebastian Hahn, Stefan Hasenauer, Richard Kidd, Wouter Dorigo, Wolfgang Wagner, Vincenzo Levizzani

Precipitation

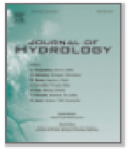
↑

Soil moisture

ELSEVIER

Journal of Hydrology

Volume 556, January 2018, Pages 993-1012



Research papers

Spatiotemporal patterns of precipitation inferred from streamflow observations across the Sierra Nevada mountain range

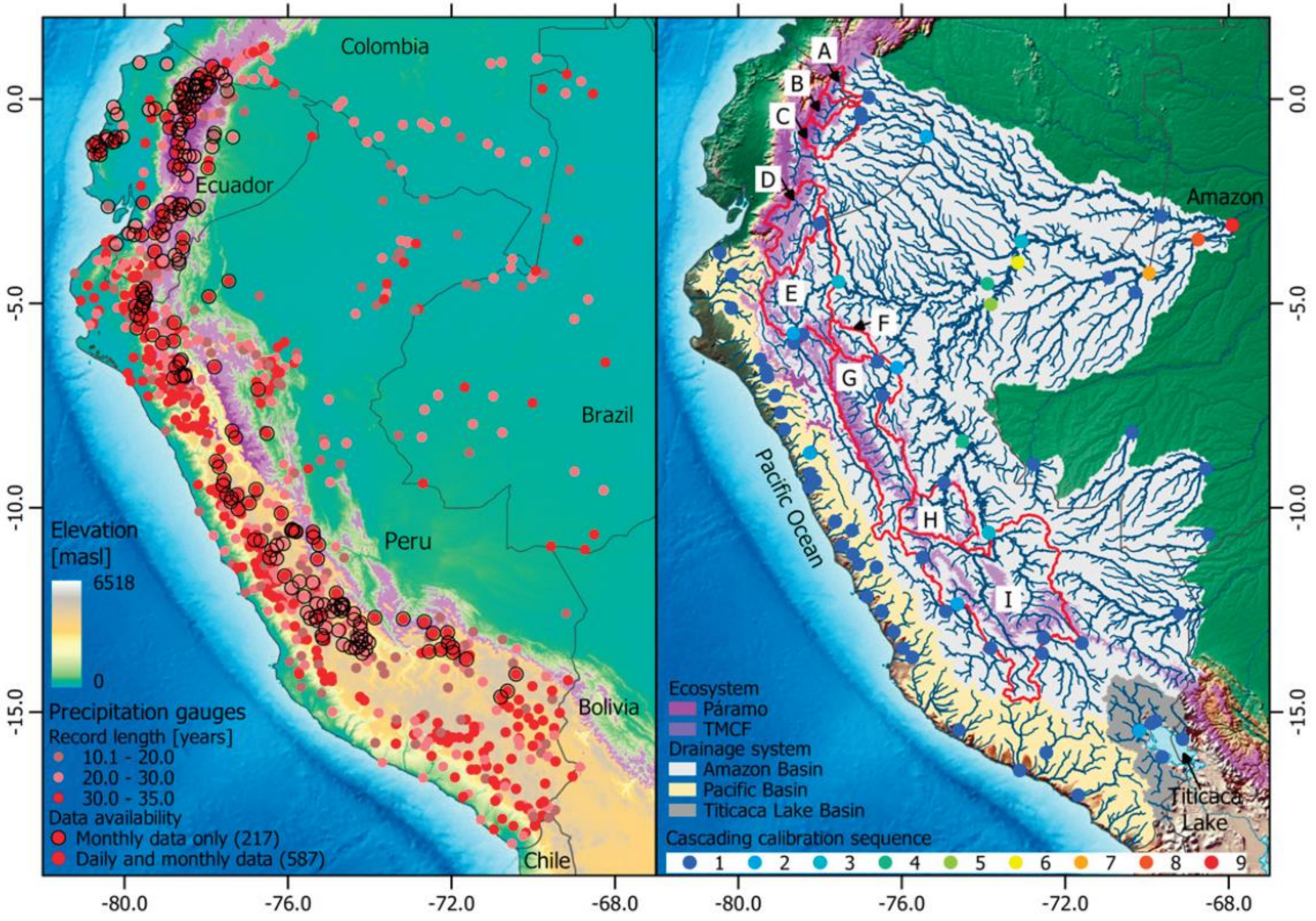
Brian Henn [a], Martyn P. Clark [b], Dmitri Kavetski [c], Andrew J. Newman [b], Mimi Hughes [d, e], Bruce McGurk [f], Jessica D. Lundquist [g]

Precipitation

↑

Streamflow

Study area and data



Precipitation gauges (804)

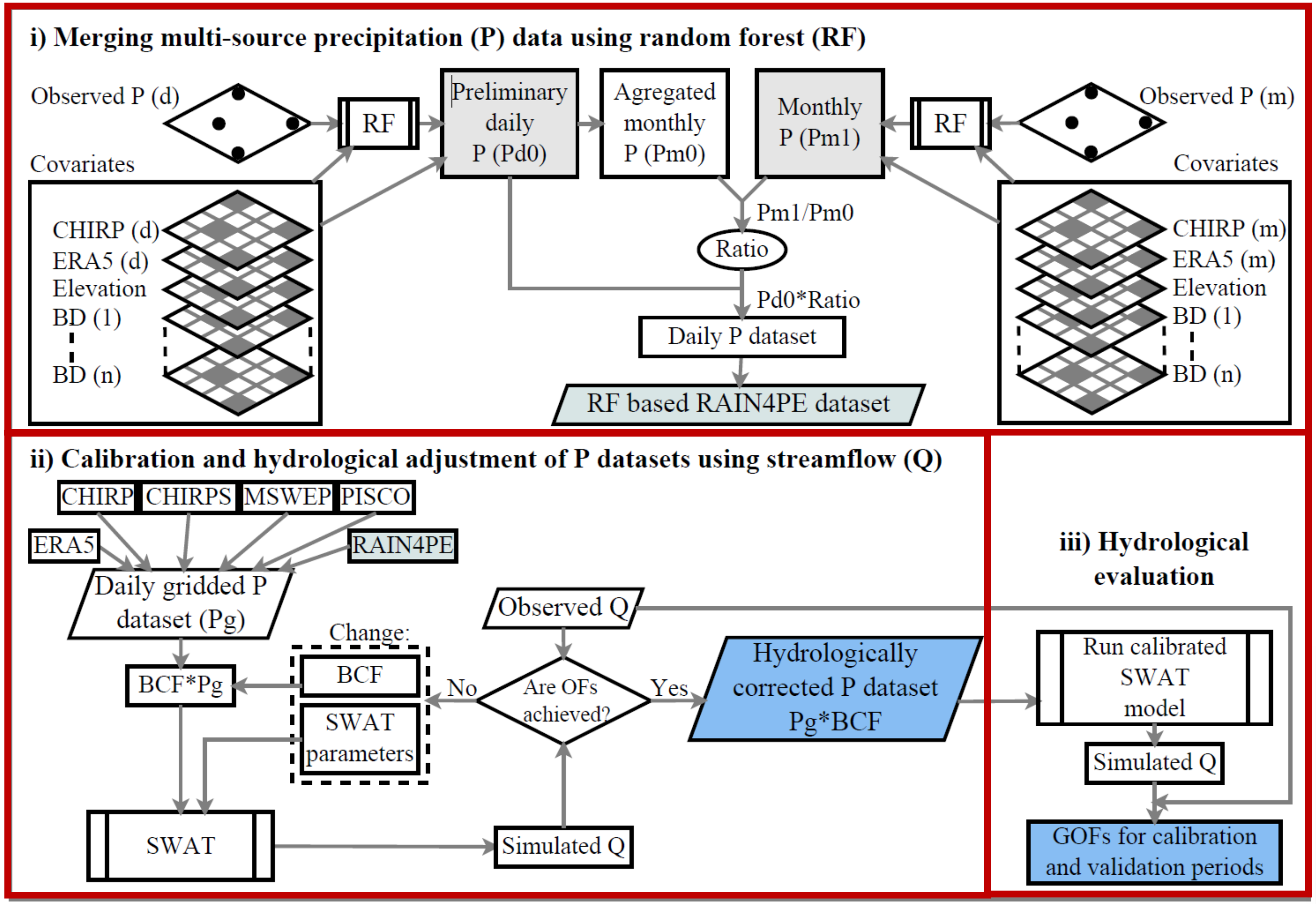
streamflow stations (72)

Data for the precipitation estimation

- ❑ Precipitation sources
  - ✓ Gauge-based precipitation
  - ✓ Satellite-based precipitation (CHIRP dataset)
  - ✓ Reanalysis-based precipitation (ERA5 dataset)
- ❑ Elevation
- ❑ Streamflow

Red polygons show the gauged catchments with water budget imbalance where gridded precipitation datasets are corrected using streamflow data through reverse hydrology: Nueva Loja station gauges the catchment “A”, San Sebastian (B), Francisco De Orellana (C), Santiago (D), Borja (E), Shanao (F), Chazuta (G), Puerto Inca (H), Lagarto (I).

Methodology



- Here “d” (“m”) indicates the daily (monthly) time step
- BDi,..n are buffer distances (distance from any point to all precipitation gauges)
- **SWAT** is the Soil and Water Assessment Tool
- BCF is the bias correction factor
- **OFs** are the objective functions for hydrological model calibration (log NSE y FDC signatures)
- **BCF** is optimized only over catchments with water budget imbalance
- Optimization algorithm: **Borg MOEA**
- GOFs are the goodness of fit measures

Model calibration is based on our previous study:

HYDROLOGICAL SCIENCES JOURNAL
https://doi.org/10.1080/02626667.2020.1846740

Check for updates

Towards a more consistent eco-hydrological modelling through multi-objective calibration: a case study in the Andean Vilcanota River basin, Peru

Carlos Antonio Fernandez-Palomino[a,b], Fred F. Hattermann[a], Valentina Krysanova[a], Fiorella Vega-Jácome[c] and Axel Bronstert[b,d]

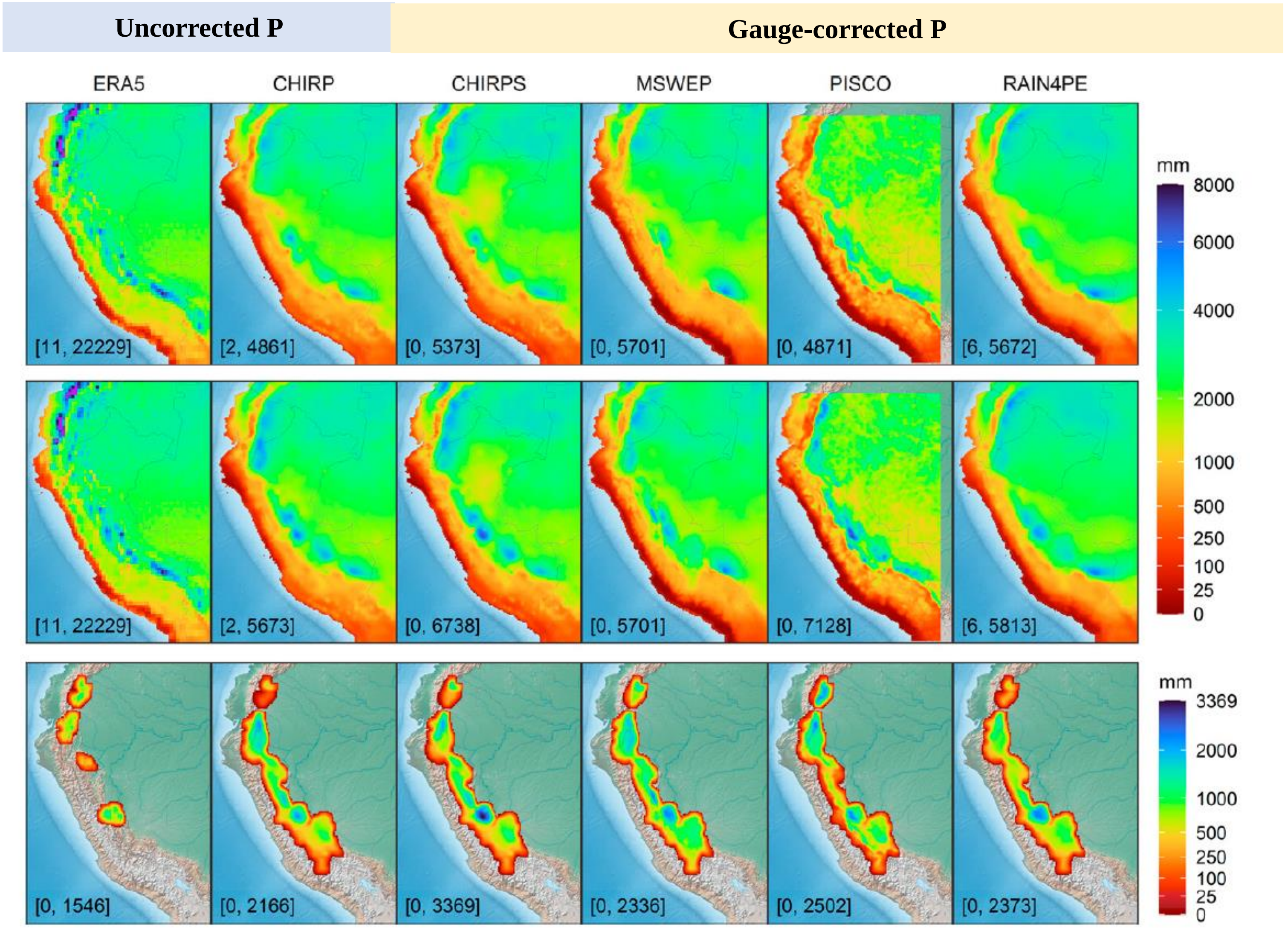
[a]Research Department II – Climate Resilience, Potsdam Institute for Climate Impact Research, Potsdam, Germany; [b]Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany; [c]Hidrología – Estudios e Investigaciones Hidrológicas, Servicio Nacional de Meteorología e Hidrología del Perú, LIMA, Peru; [d]Water Science Group, Potsdam Institute for Climate Impact Research, Potsdam, Germany

Results: spatial patterns of precipitation

(a) Annual precipitation climatology (1981-2015)

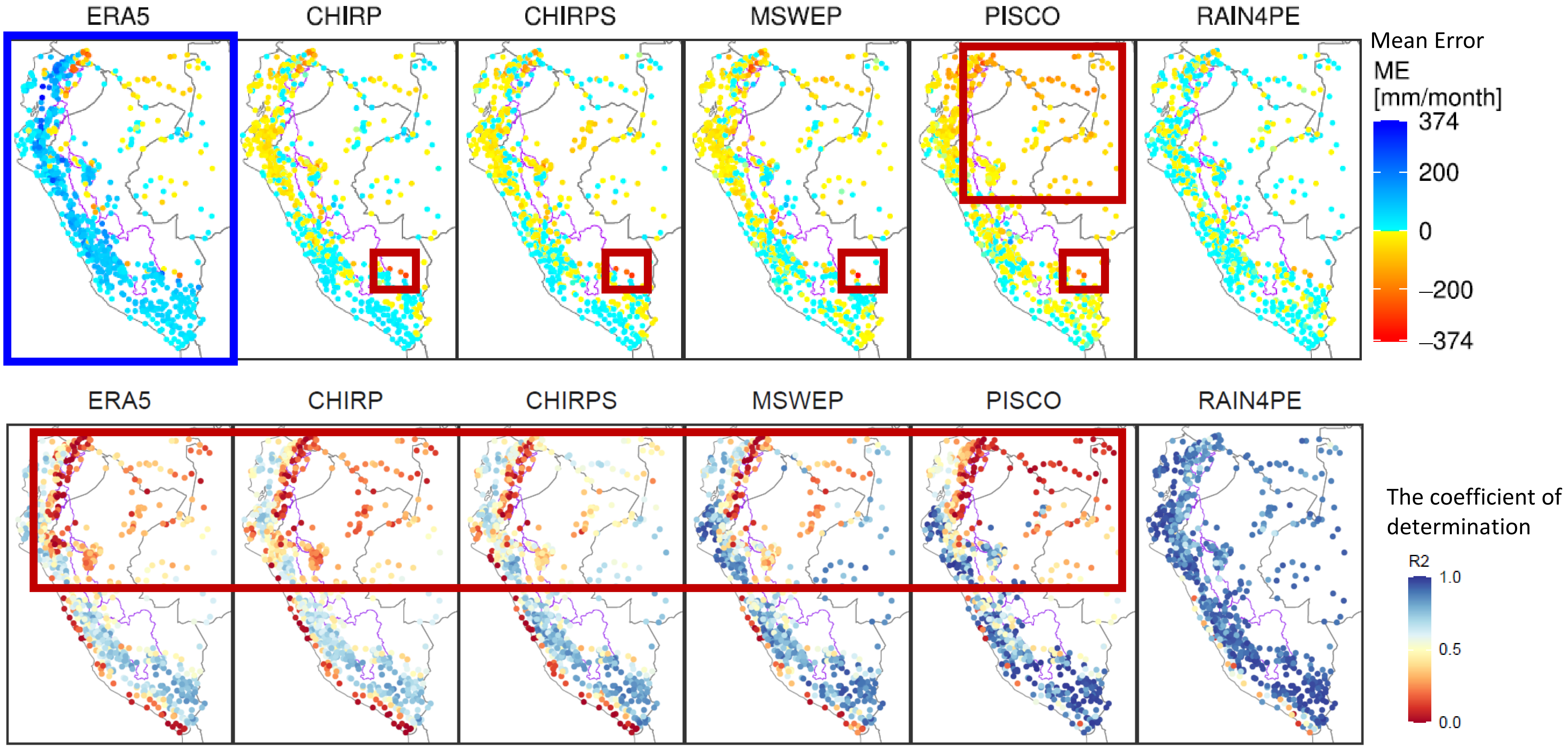
(b) Annual precipitation climatology (1981-2015) corrected using Q through reverse hydrology to achieve water balance closure

(b-a) Amount of precipitation under-estimated over montane watersheds



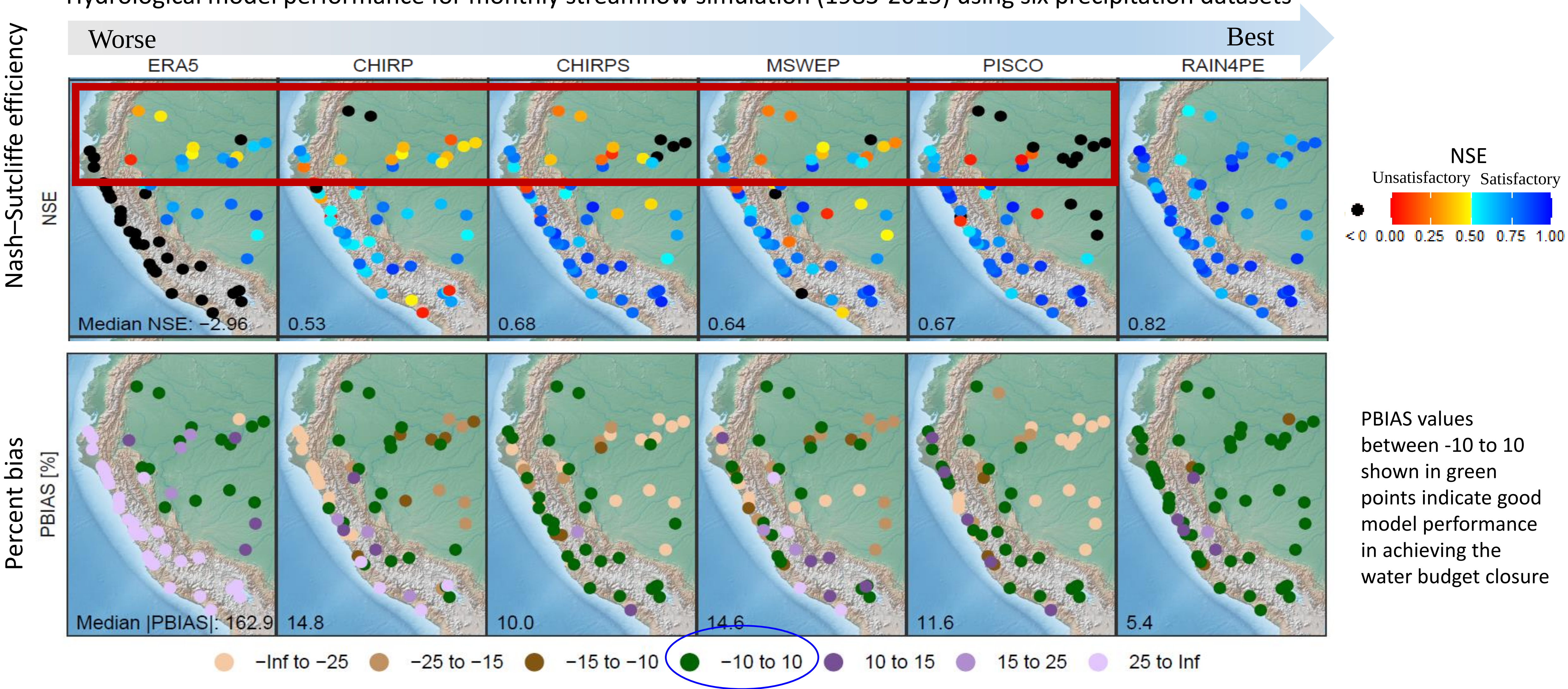
Which precipitation datasets are reliable?

Comparison of precipitation datasets using gauge observations at monthly scale for 1981-2015



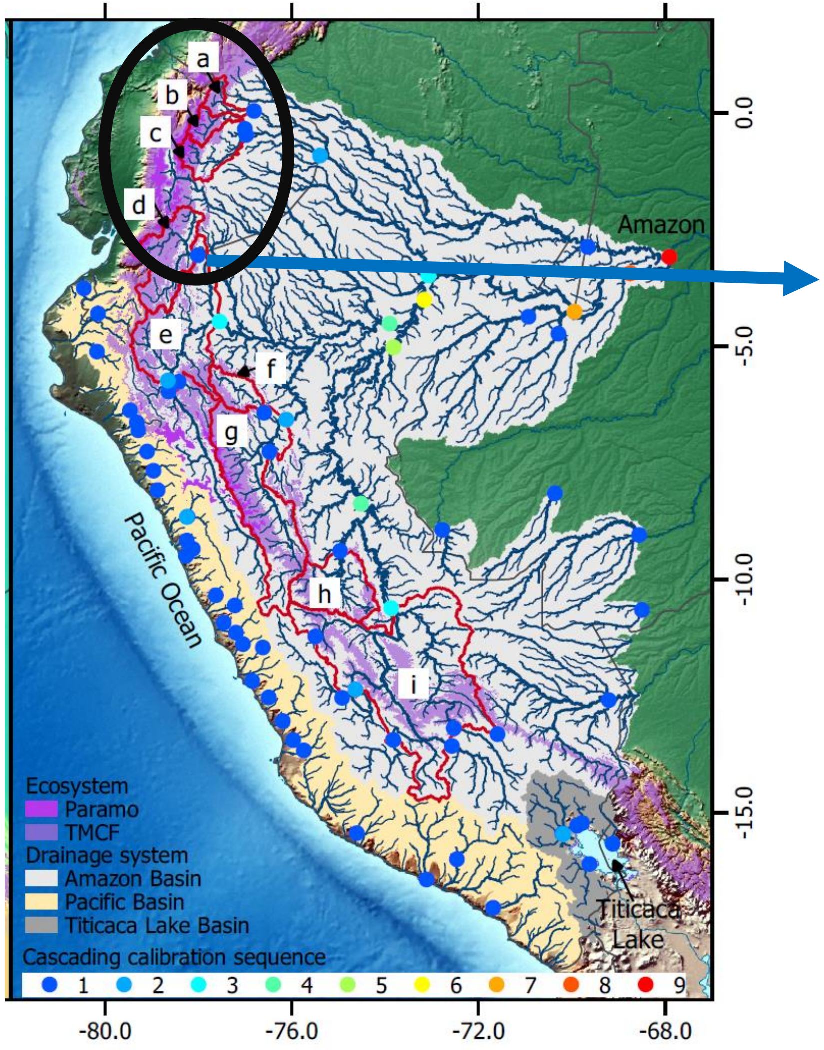
Which precipitation products are reliable for hydrological modeling using the Soil and Water Assessment Tool (SWAT) model?

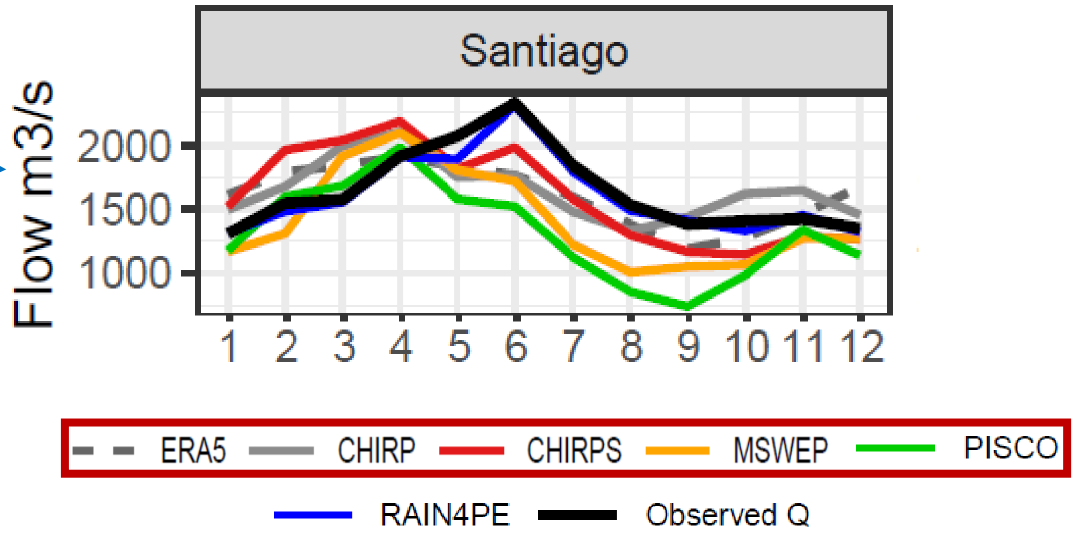
Hydrological model performance for monthly streamflow simulation (1983-2015) using six precipitation datasets



PBIAS values between -10 to 10 shown in green points indicate good model performance in achieving the water budget closure

Why do most of the precipitation datasets show unsatisfactory performance for streamflow simulation of Ecuadorian basins?





RAIN4PE data availability

- ✓ Daily precipitation data in NetCDF format can be downloaded from https://doi.org/10.5880/pik.2020.010


Impressum

POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

P I K

Dataset

Rain for Peru and Ecuador (RAIN4PE)

Released

Cite as:

Copy citation to clipboard

Fernandez-Palomino, Carlos Antonio; Hattermann, Fred F.; Krysanova, Valentina; Lobanova, Anastasia; Vega-Jácome, Fiorella; Lavado, Waldo; Santini, William; Aybar, Cesar; Bronstert, Axel (2021): Rain for Peru and Ecuador (RAIN4PE). V. 1.0. GFZ Data Services. https://doi.org/10.5880/pik.2020.010

Files

Download data and description

License: CC BY 4.0

Dataset Description

Supplement to

Fernandez-Palomino, C. A.; Hattermann, F. F.; Krysanova, V.; Lobanova, A.; Vega-Jácome, F.; Lavado, W.; Santini, W.; Aybar, C.; Bronstert, A. (2021). A novel high-resolution gridded precipitation dataset for Peruvian and Ecuadorian watersheds – development and hydrological evaluation. *Journal of Hydrometeorology*. https://doi.org/10.1175/jhm-d-20-0285.1

Abstract

RAIN4PE is a novel daily gridded precipitation dataset obtained by merging multi-source precipitation data (satellite-based Climate Hazards Group InfraRed Precipitation, CHIRP (Funk et al. 2015), reanalysis ERA5 (Hersbach et al. 2020), and ground-based precipitation) with terrain elevation using the random forest regression method. Furthermore, RAIN4PE is hydrologically corrected using streamflow data in catchments with precipitation underestimation through reverse hydrology. Hence, RAIN4PE is the only gridded precipitation product for Peru and Ecuador, which benefits from maximum available in-situ observations, multiple precipitation sources, elevation data, and is supplemented by streamflow data to correct the precipitation underestimation over páramos and montane catchments.

The RAIN4PE data are available for the terrestrial land surface between 19°S-2°N and 82-67°W, at 0.1° spatial and daily temporal resolution from 1981 to 2015. The precipitation dataset is provided in netCDF format.

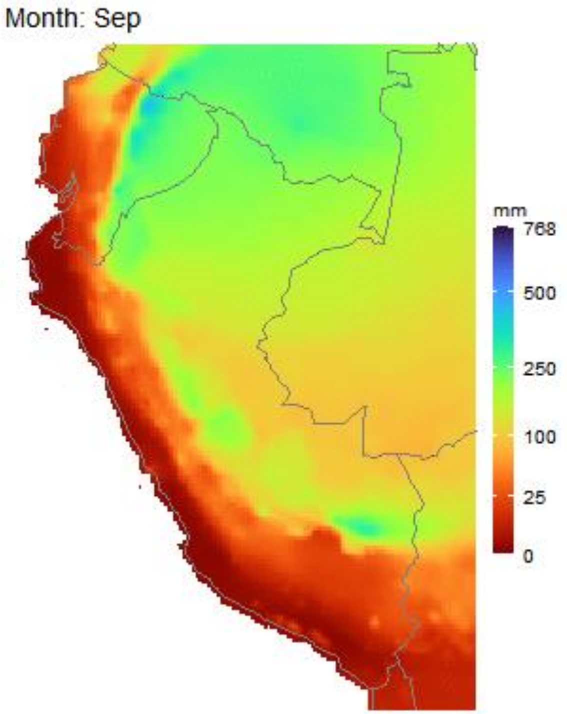
For a detailed description of the RAIN4PE development and evaluation of RAIN4PE applicability for hydrological modeling of Peruvian and Ecuadorian watersheds, readers are advised to read Fernandez-Palomino et al. (2021).

Additional Information

Acknowledgements

The authors thank the East Africa Peru India Climate Capacities (EPICC) Project for funding this research within the International Climate Initiative (IKI) funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

- ✓ The data is also available to download using the Google Earth Engine platform from awesome-gee-community-datasets



More details about RAIN4PE in:

FERNANDEZ-PALOMINO ET AL.

A Novel High-Resolution Gridded Precipitation Dataset for Peruvian and Ecuadorian Watersheds: Development and Hydrological Evaluation

Conclusions

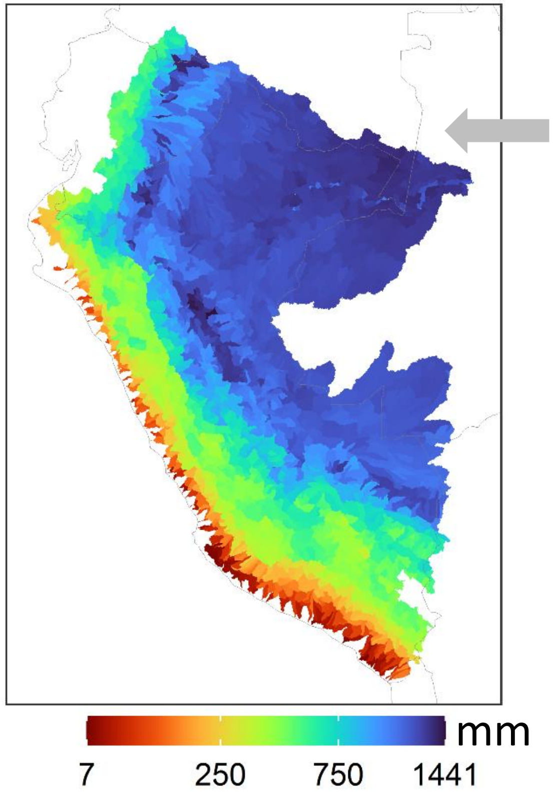
- ✓ Our precipitation product RAIN4PE resulted to be more reliable and accurate for the hydrological modeling of Peruvian and Ecuadorian watersheds compared to other precipitation products such as ERA5, CHIRP, CHIRPS, MSWEP, and PISCO.

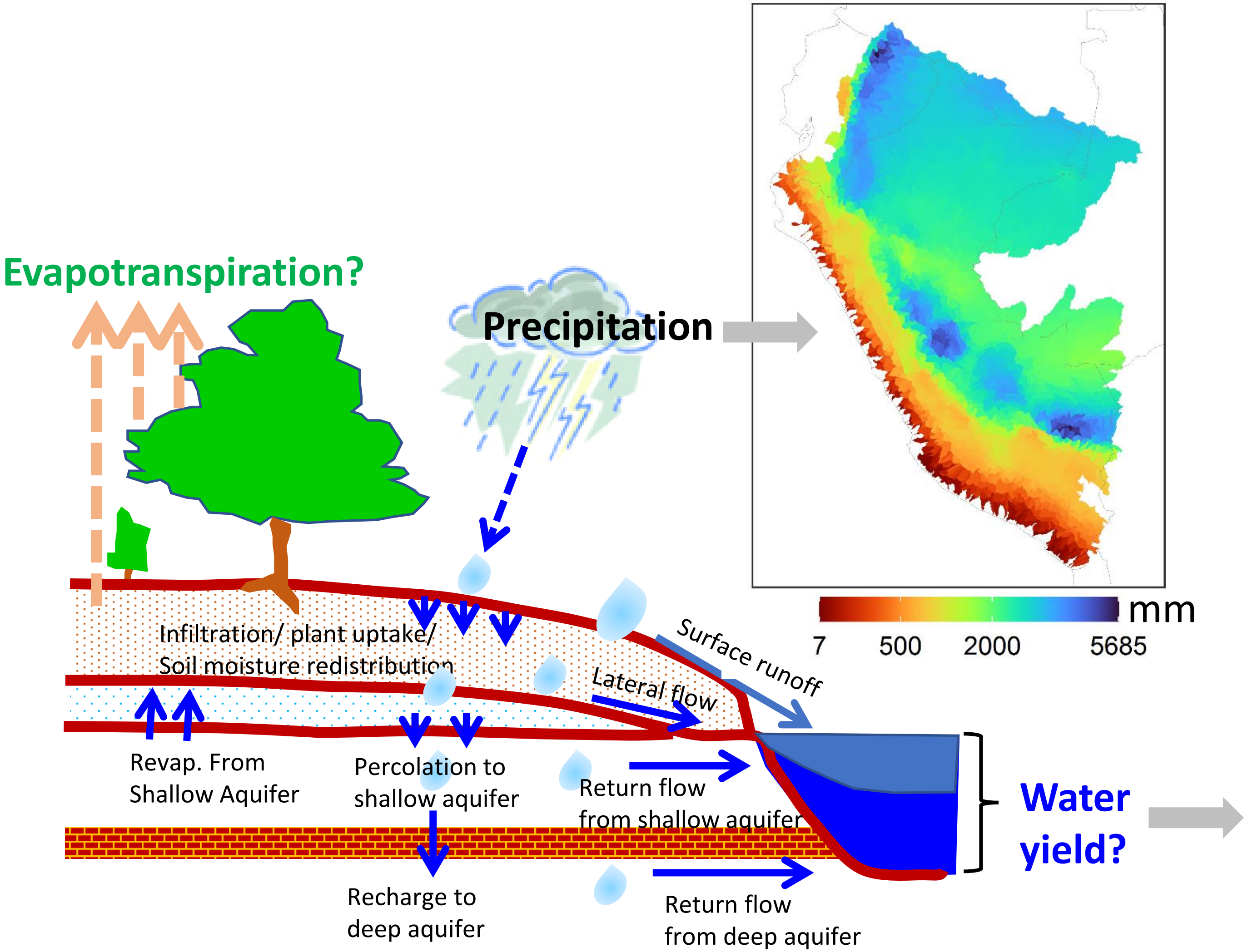
- ✓ RAIN4PE can be used for multiple hydro-meteorological applications:
  - Water budget
  - Spatio-temporal analysis of droughts and floods, etc.

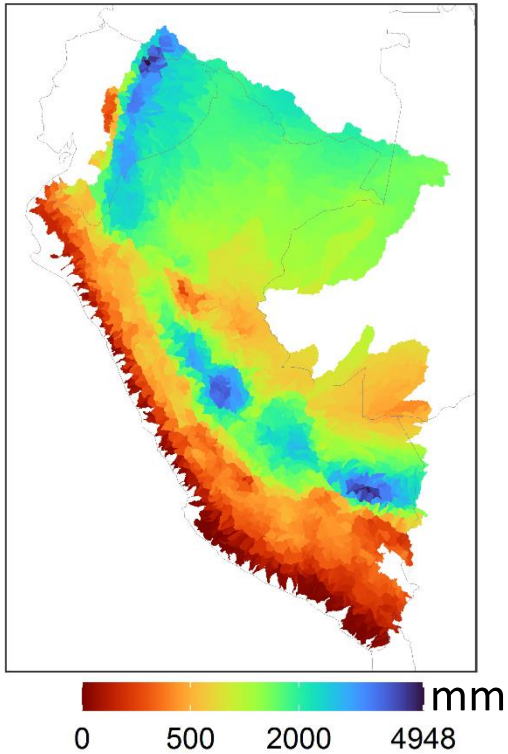
- ✓ The approach used for the generation of RAIN4PE can be used in other data-scarce regions. E.g. for amazon basin or south America

Spatial variability of the water budget components (1985-2015)

- Hydrological model: SWAT driven by RAIN4PE precipitation data





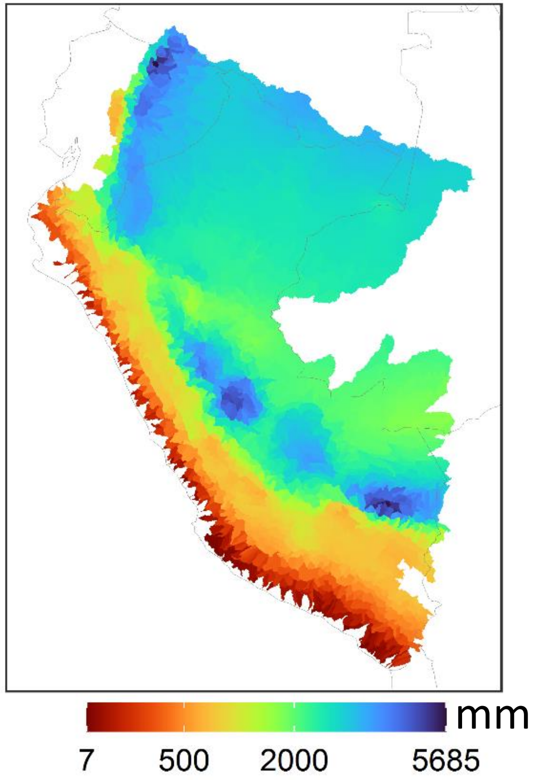


The water budget at national scale of Peru was estimated for the first time which is a big step and will benefit the water resources management

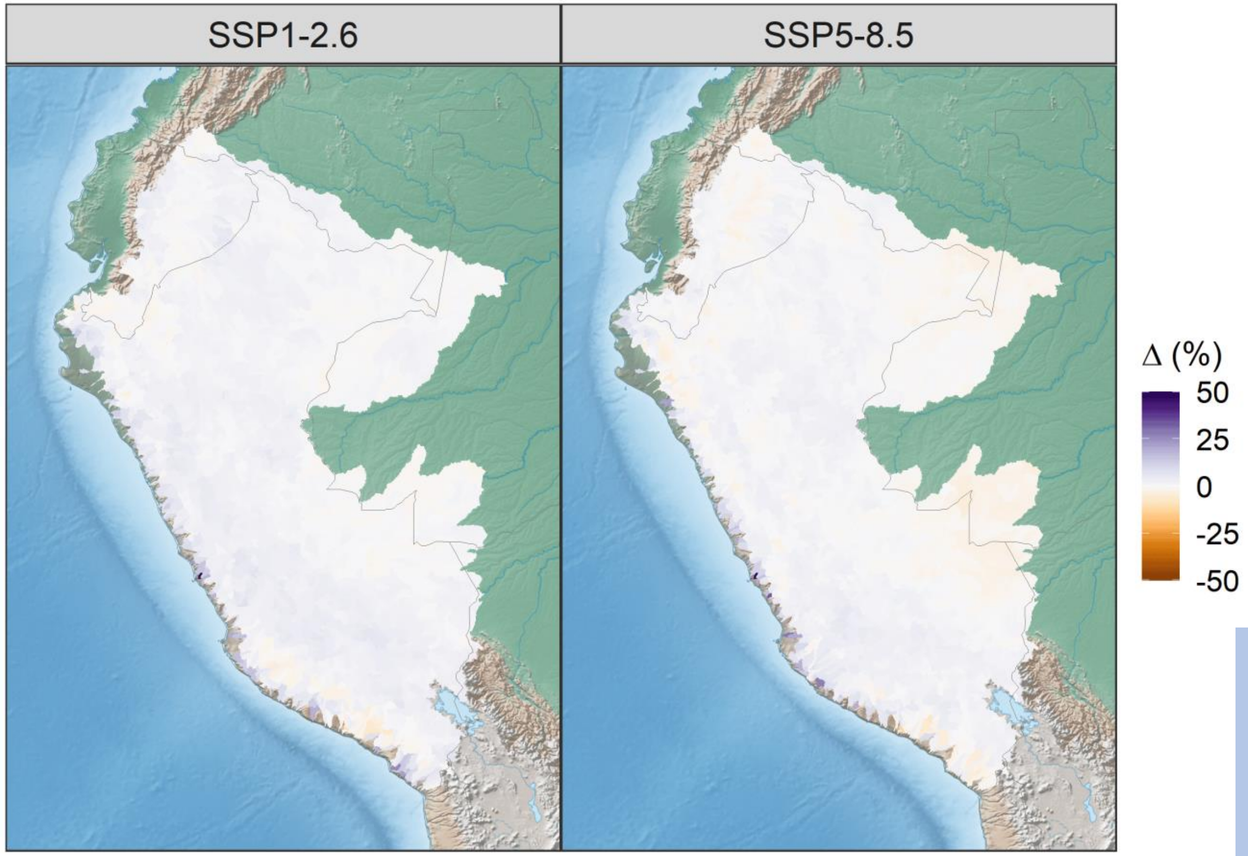
Projected spatiotemporal changes in water budget components under climate change

Precipitation

Ref. period: 1985-2015



Period: 2005-2035



The maps show the ensemble median values of the climatological percent changes for precipitation under SSP1-2.6 and SSP5-8.5 compared to the historical period (1985–2015)

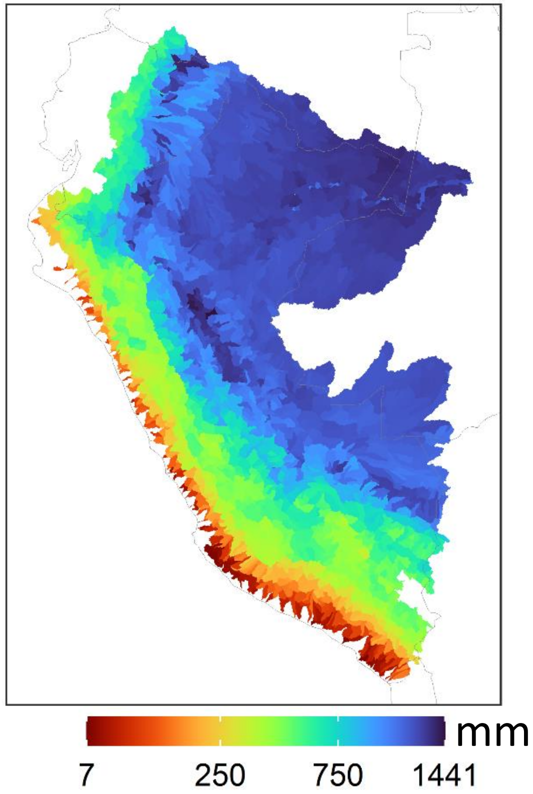
↓precipitation over lowlands (specially over the southern lowland)

↑precipitation along the Peruvian Andes

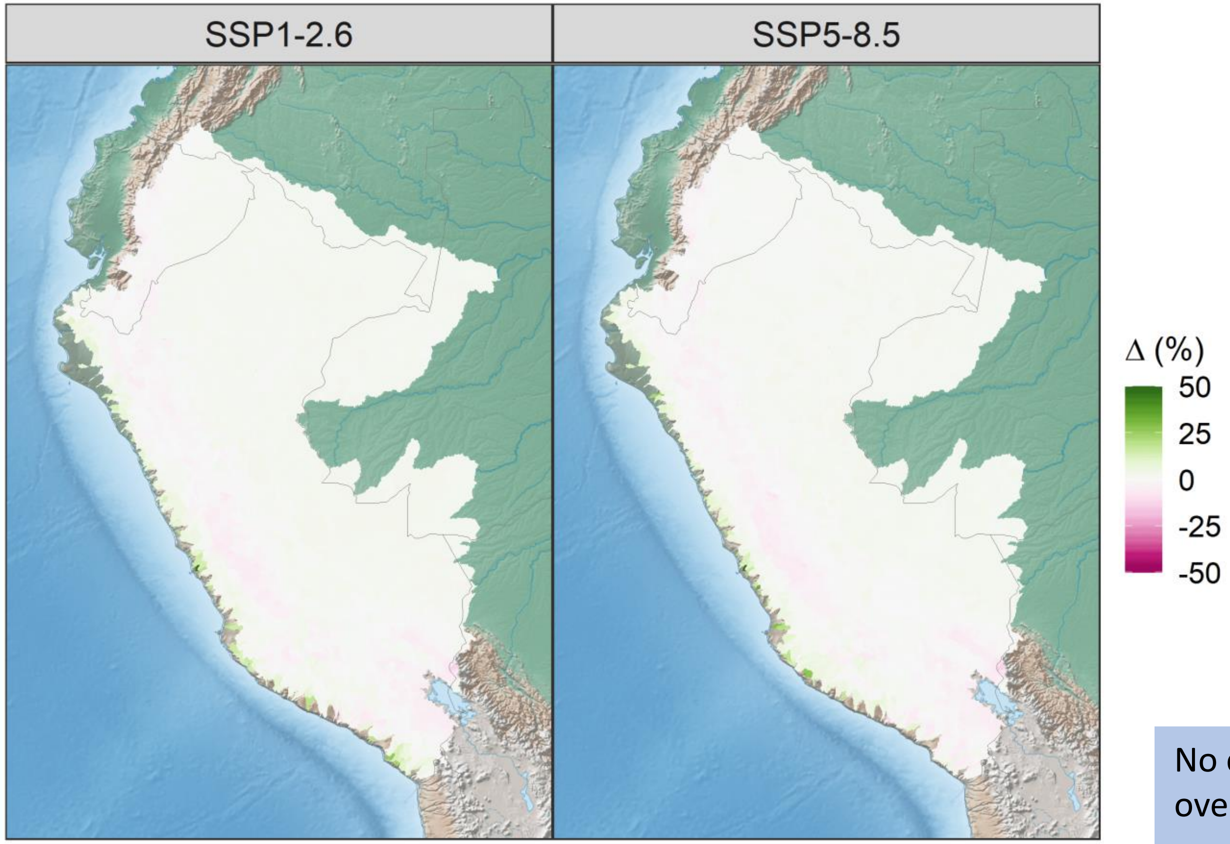
Projected spatiotemporal changes in water budget components under climate change

Evapotranspiration

Ref. period: 1985-2015



Period: 2005-2035



The maps show the ensemble median values of the climatological percent changes for evapotranspiration under SSP1-2.6 and SSP5-8.5 compared to the historical period (1985–2015)

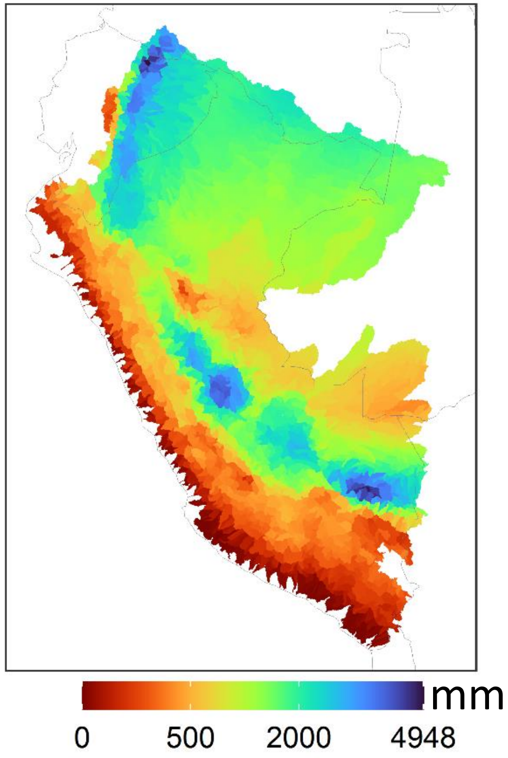
No changes in evapotranspiration over Andean basins

↑evapotranspiration over the lowland and arid coastal areas

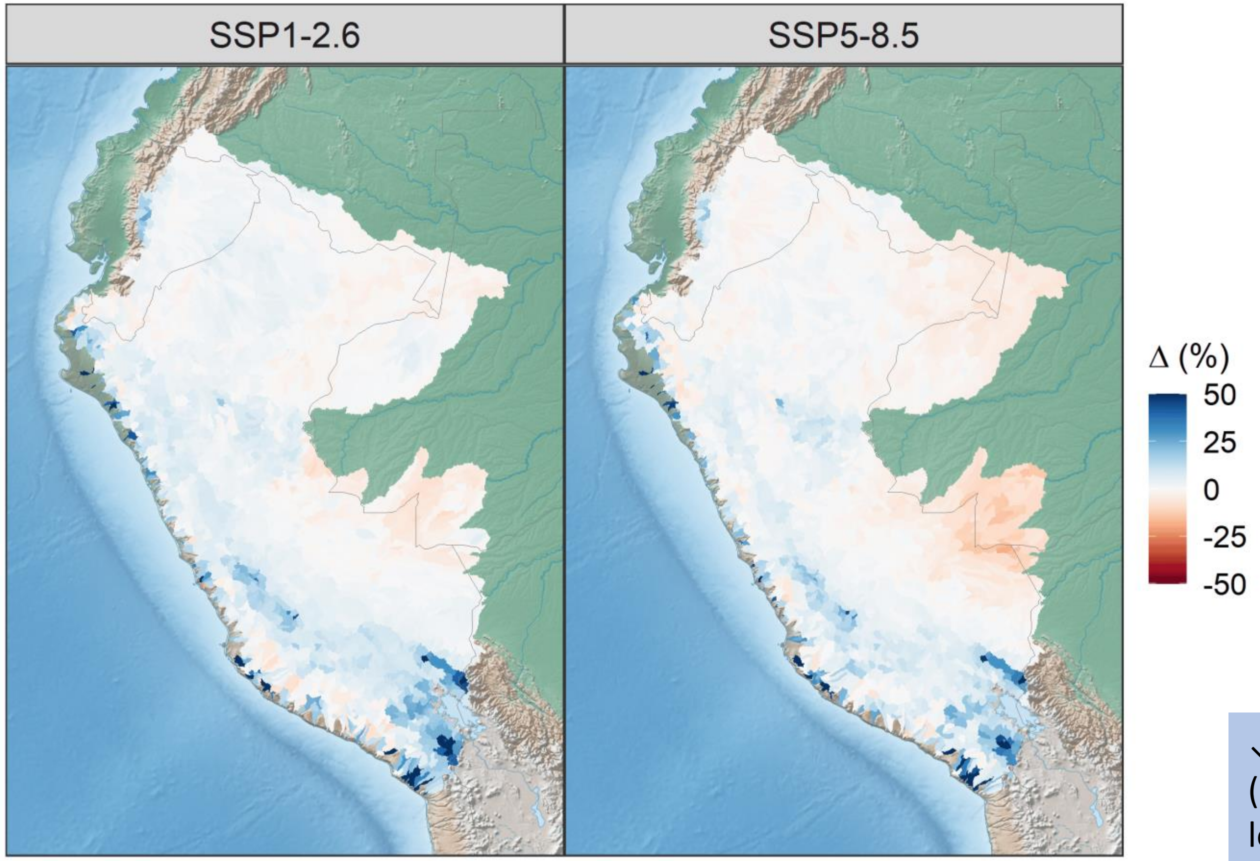
Projected spatiotemporal changes in water budget components under climate change

Water yield

Ref. period: 1985-2015



Period: 2005-2035



The maps show the ensemble median values of the climatological percent changes for water yield under SSP1-2.6 and SSP5-8.5 compared to the historical period (1985–2015)

↓water yield over lowlands (specially over the southern lowland)

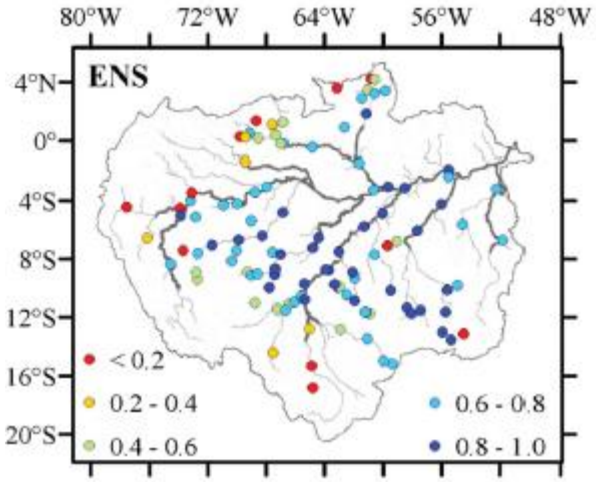
↑water yield along the Andean basins

Planned activities for Brazil

- **Generation of the new precipitation data for Amazon/south America based on our gained experience in Peru**
- Analysis of water budget of Amazon River Basin and its sensitivity to climate change

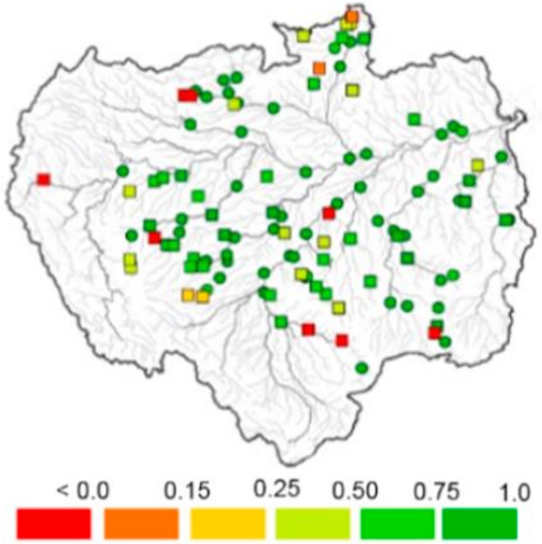
Motivation: Poor performance of hydrological model using different precipitation (P) datasets in the upper Amazon River Basin

TRMM 3B42



Paiva et al. 2013

ERA-20CM



Correa et al. 2019

Nash–Sutcliffe efficiency (NSE)

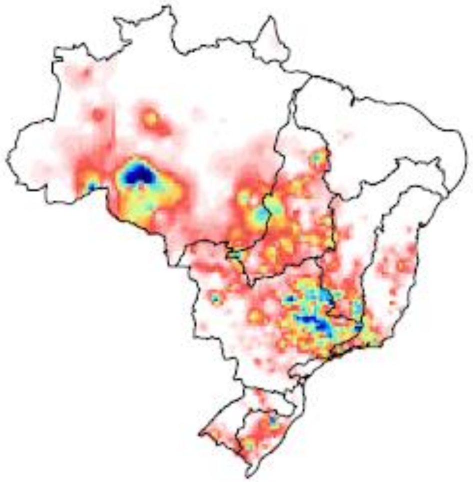
Data: observed precipitation (P) data for 1981-2015

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **36**: 2644–2659 (2016)
Published online 8 October 2015 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.4518

RMetS
Royal Meteorological Society

Daily gridded meteorological variables in Brazil (1980–2013)

Alexandre C. Xavier,[a] Carey W. King[b*] and Bridget R. Scanlon[c]
[a] *Department of Rural Engineering, Federal University of Espírito Santo, Vitória, Brazil*
[b] *Energy Institute, The University of Texas at Austin, TX, USA*
[c] *Bureau of Economic Geology, The Jackson School of Geosciences, The University of Texas at Austin, TX, USA*



PIK

Leibniz Association

Is the generation of gridded precipitation data for Amazon/South America of your interest?

How can we obtain the observed precipitation and discharge data?

How can we collaborate with your institution?

THANKS