Climate Change Impact on Water Budget and Hydrological Extremes Across Peru

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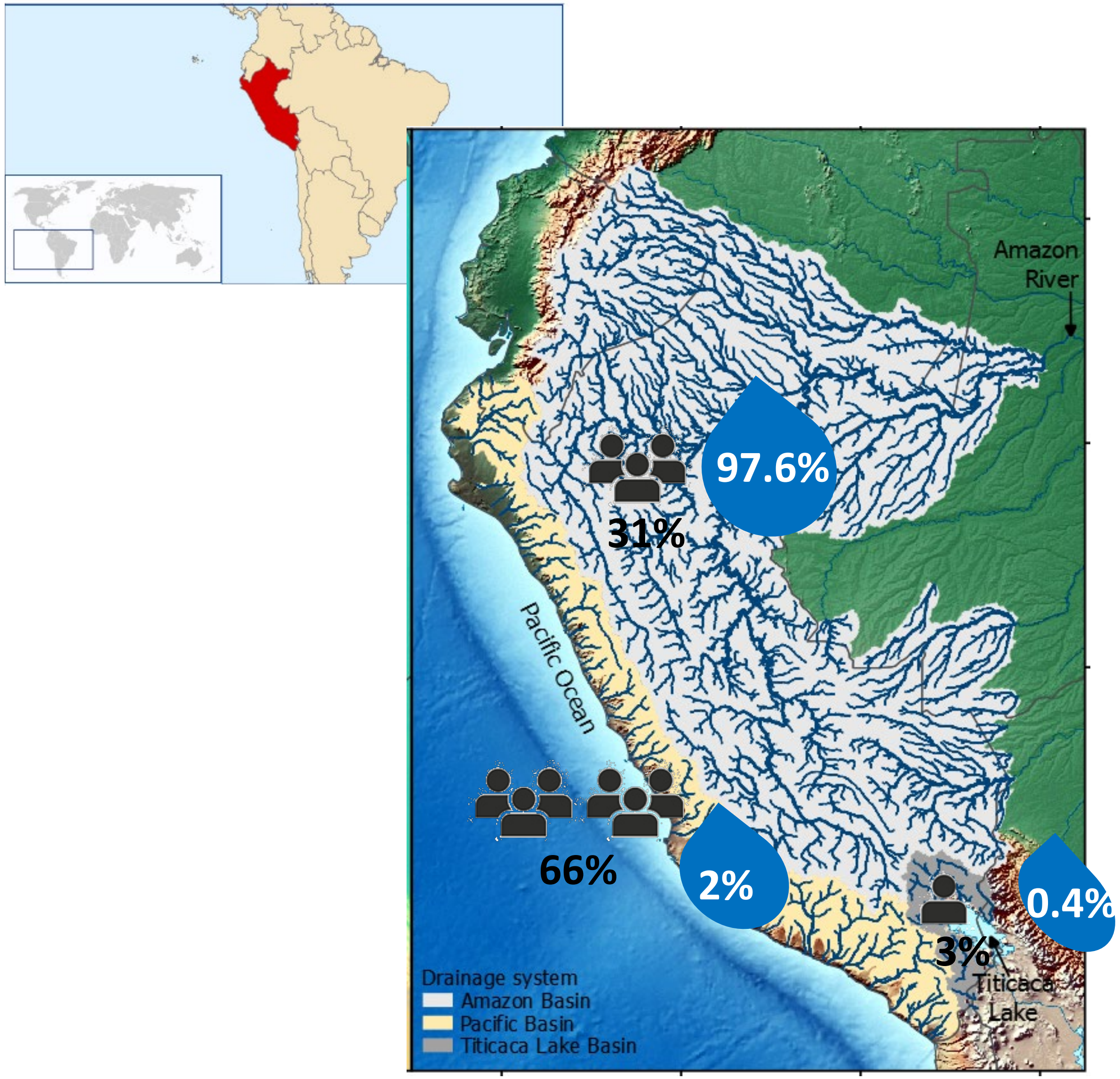
Peru and its water resources distribution



Population
33 Millions

Water resources availability
58,934 m3/s

Uneven water availability across the three large drainage systems

Evidences of extreme climate variability and climate change

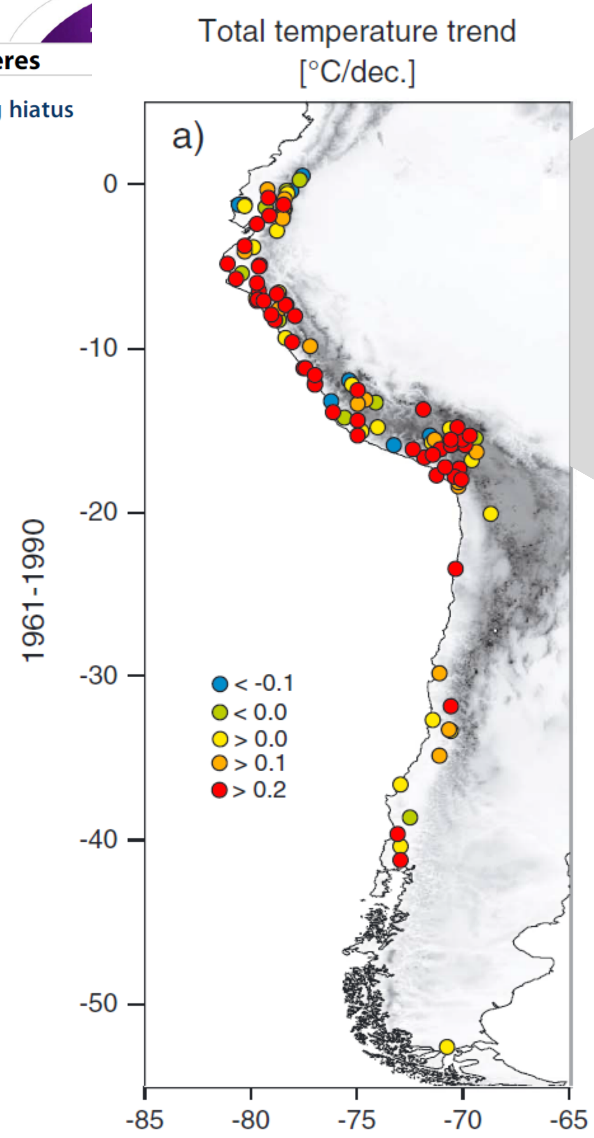
Changes in temperature

AGU PUBLICATIONS

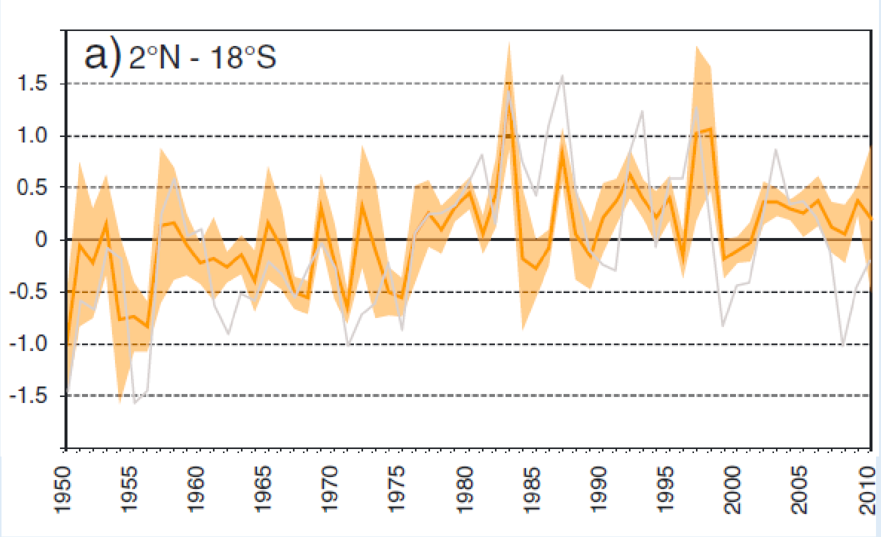
Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE
10.1002/2015JD023126

Impact of the global warming hiatus on Andean temperature



Annual mean temperature anomaly compared to 1961-1990 average



In tropical Andes (2°N–18°S),
a significant warming trend of
0.13°C/decade
over 1950–2010
have been observed.

Evidences of extreme climate variability and climate change

Changes in glacier

Contents lists available at ScienceDirect

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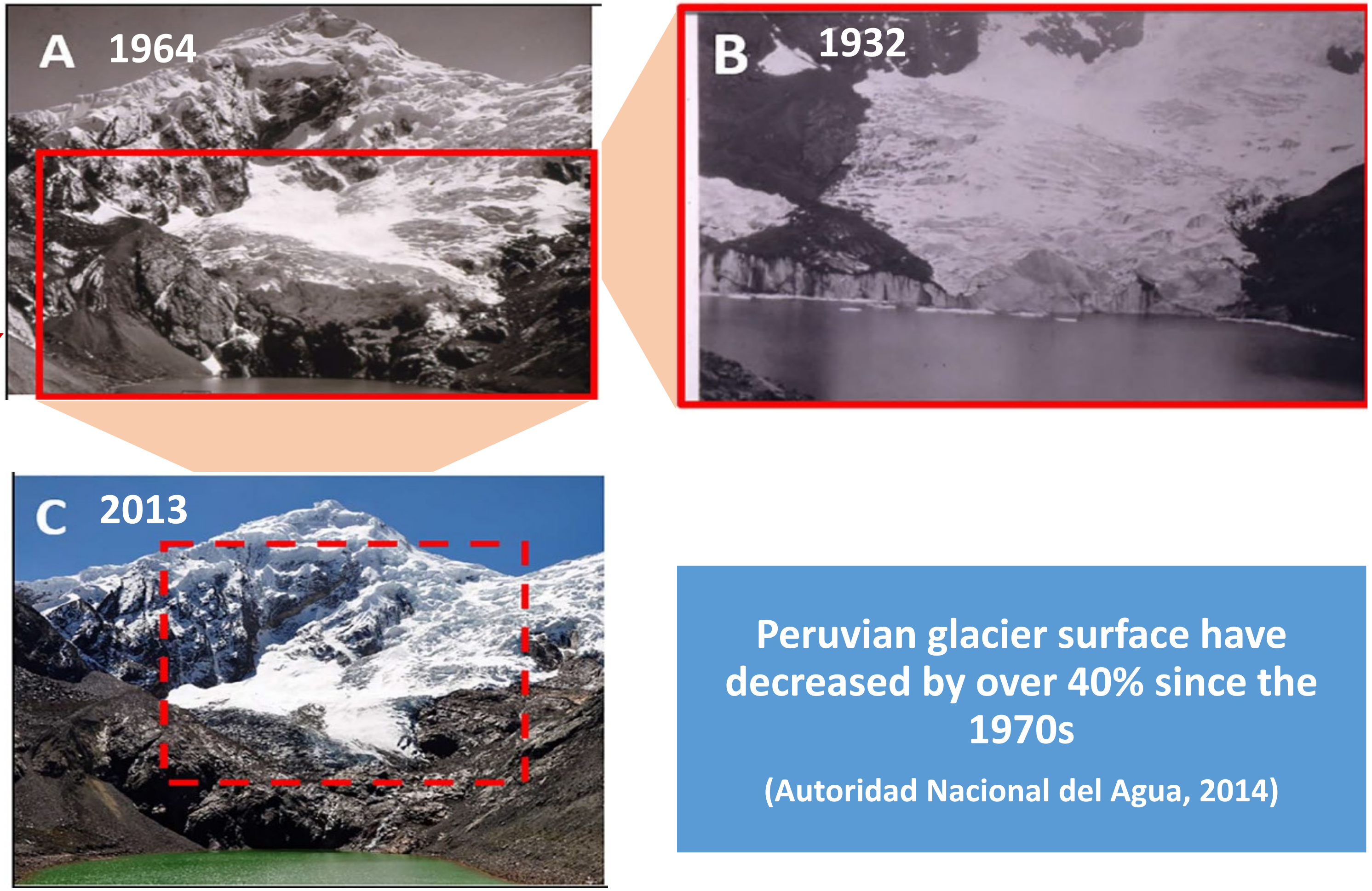
Glacier loss and hydro-social risks in the Peruvian Andes

Cuchillacocha glacier



Peruvian glacier surface have decreased by over 40% since the 1970s

(Autoridad Nacional del Agua, 2014)

Evidences of extreme climate variability and climate change

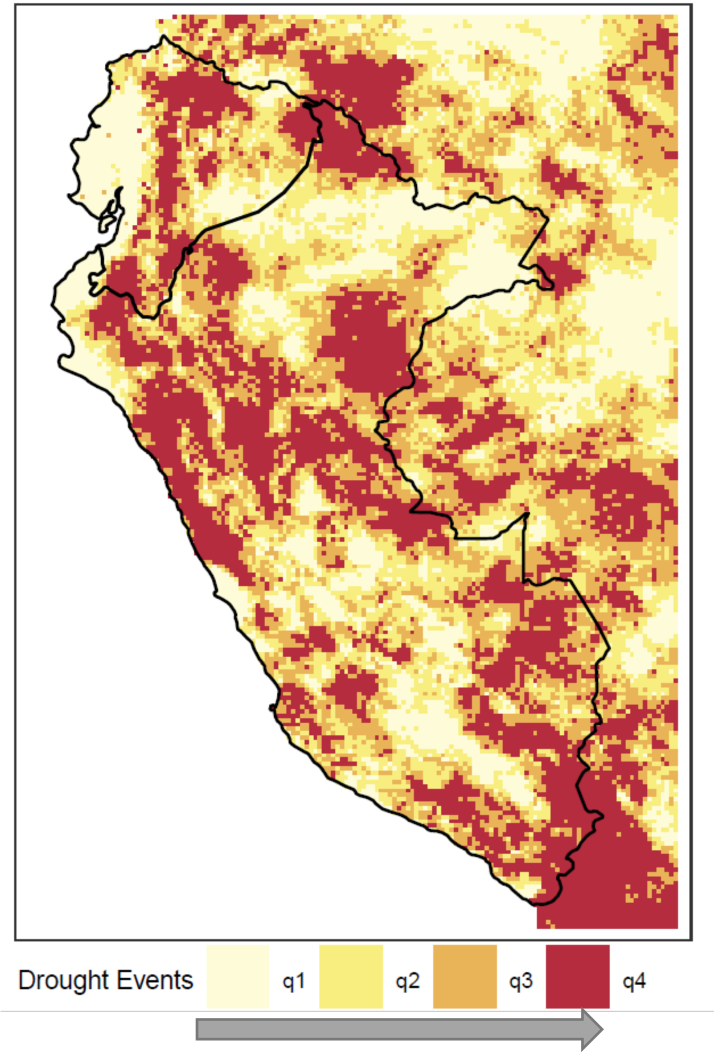
Intensification of:

Floods

Flooding in Iquitos during the historic flooding of the upper Amazon river, 2012

Flooding in Lima during „Coastal El Nino", 2017

Droughts



Red areas indicate higher frequency of drought events between 1981-2015

The aforementioned climate change evidences should be a “wake-up call” for:

- Scientist to research the current and future hydro-climate conditions
- Governments, local leaders, and people to improve their preparedness for extreme weather events

To support these “wake-up calls”, our present study analyze the impact of climate change on water resources of PERU.

Objectives

- To evaluate the effects of climate change on the distribution of water budget components and streamflow variability across Peru, including transboundary catchments

Previous presentations

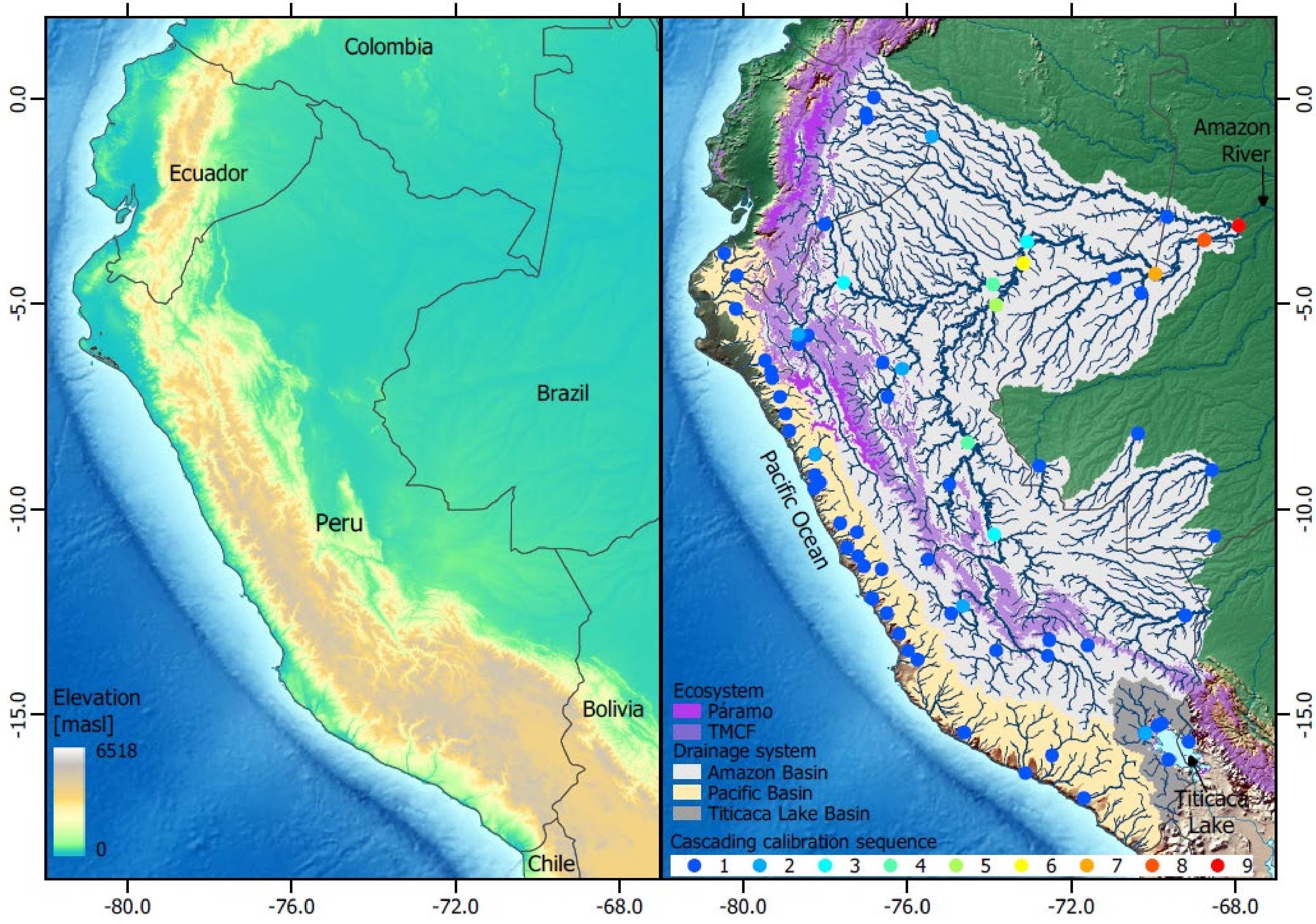
Carlos Antonio Fernandez Palomino

Distribution and Partitioning of Water Balance Components in Peru along a Variety of Landscapes from the High Andes to the Amazon Rain Forest: Insights from a National-Scale Analysis

Carlos Antonio Fernandez Palomino

Assessing the Impact of Precipitation Input Errors on Model Parameters and Water Budget Components: Insights from Countrywide Hydrological Modeling in Peru

Study area



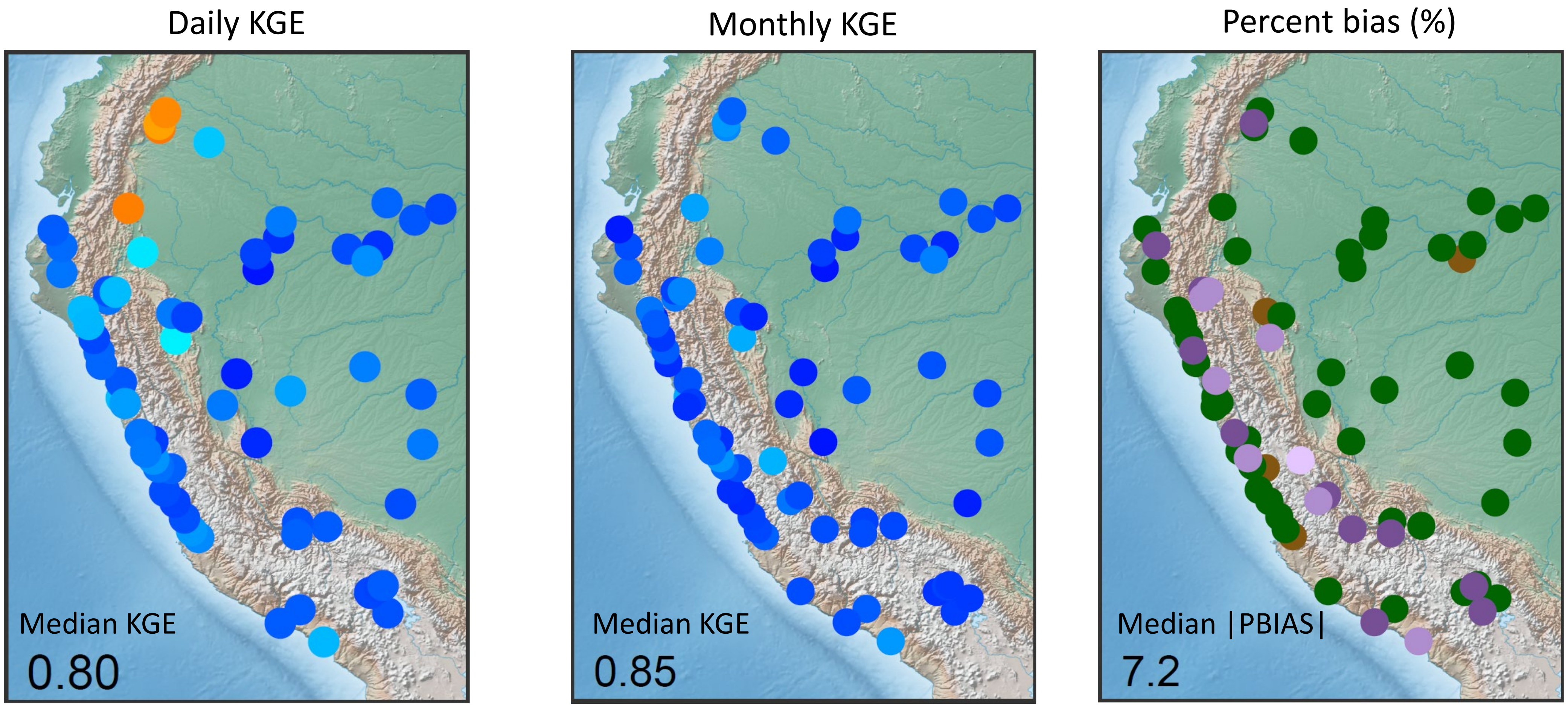
Streamflow stations (72)

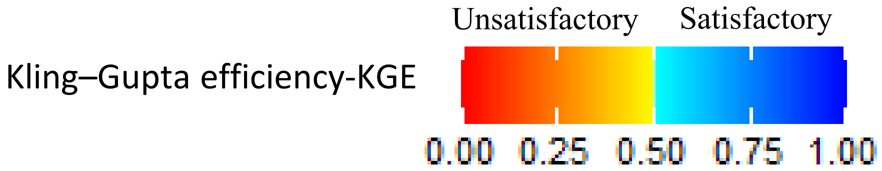
Model setup
Area: 1.6 Million km^2
2675 subcatchments
6843 HRUs

Data

Data type	Resolution	Description/source
Spatial data		
Elevation	90 m	Surface elevation (m a.s.l.) from Multi-Error-Removed Improved Terrain (MERIT; Yamazaki et al. 2017)
Land use	100 m	Land use classification representative for the year 2015 obtained from Copernicus Global Land Service (Buchhorn et al. 2019)
Soil	1000 m	Soil parameters for SWAT based on the Harmonized World Soil Database version 1.21 soil data (Abbaspour and Ashraf Vaghefi 2019)
Soil thickness	1000 m	Soil thickness data (Pelletier et al. 2016) were used to implement variable soil thicknesses at hydrological response units (HRUs)
Groundwater table depth	1000 m	Groundwater table depth data (Fan et al. 2013) were used to constrain soil thickness in shallow water tables across the rainforest region
Hydro-meteorological data		
Precipitation	Daily/0.1° (1981 – 2015)	Rain for Peru and Ecuador (RAIN4PE; Fernandez-Palomino et al. 2021a,b)
Temperature	Daily/0.1° (1981-2016)	Gridded temperature (maximum and minimum) dataset for Peru (Huerta et al. 2018) as provided by SENAMHI (ftp://publi_dgh2:123456@ftp.senamhi.gob.pe/)
Solar radiation	3-hourly/0.1° (1983-2018)	Long-term monthly averages of solar radiation based on the global surface solar radiation data (Tang et al. 2019; Tang 2019) were used
Streamflow	Daily/0.1° (1981 – 2015)	Streamflow data were obtained from Peruvian ANA, SENAMHI, and HYBAM project
Projected climate data		
Precipitation and temperature	Daily/0.7-2.8° Historic (2015 – 2100) Projected (2015 – 2100)	Precipitation and temperature (mean, maximum and minimum) from 10 CMIP6-GCMs for two scenarios (SSP1-2.6 and SSP5-8.5) were obtained from https://esgf-node.llnl.gov/search/cmip6/.

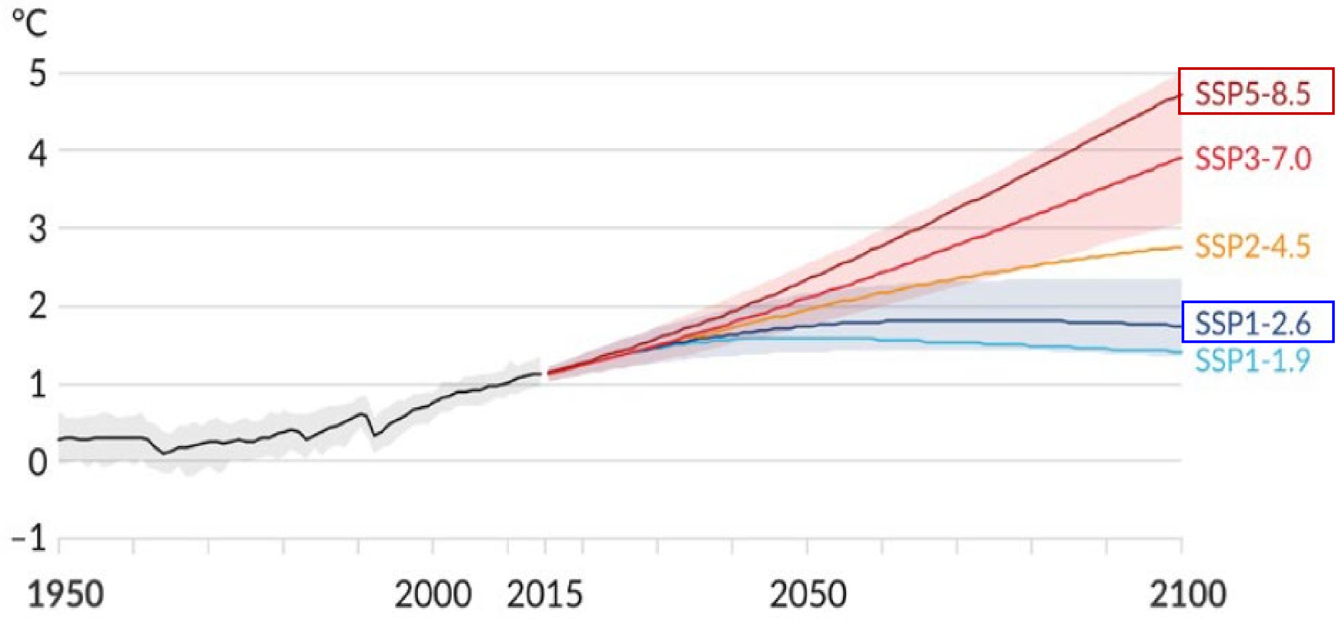
SWAT model performance for streamflow simulation





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

Future hydrological developments under two Shared Socioeconomic Pathways (SSPs)



Changes in global surface temperature in °C relative to 1850-1900. Source: IPCC AR6 (2021)

Fossil-fueled development (SSP5-8.5, with 8.5 W/m2 by the year 2100)

Sustainable pathway (SSP1-2.6, with 2.6 W/m2 by the year 2100)

BASD-CMIP6-PE: bias-adjusted and statistically downscaled CMIP6 projections over Peru and Ecuador (data paper under review)

3 scenarios	10 GCMs	4 variables	Period
• SSP1-2.6 • SSP3-7.0 • SSP5-8.5	• CanESM5 • IPSL–CM6A–LR • UKESM1–0–LL • CNRM–CM6–1 • CNRM–ESM2–1 • MIROC6 • GFDL–ESM4 • MRI–ESM2–0 • MPI–ESM1–2–HR • EC–Earth3	• Precipitation • Minimum temperature • Mean Temperature • Maximum temperature	• Historical simulation (1850–2014) • Future projections (2015–2100)

- The adjusted climate data were generated using the trend-preserving *Bias Adjustment and Statistical Downscaling method (Lange 2019)*.
- and considering reliable data from regional observational datasets such as RAIN4PE for precipitation and PISCO for temperatures as reference data.

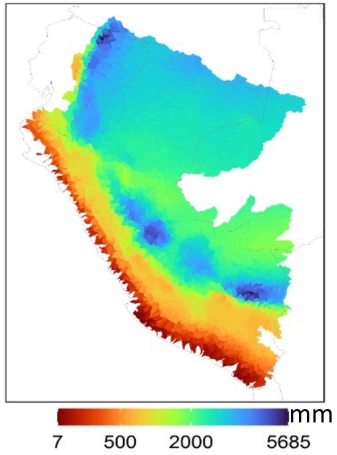
- Data (**300 GB**) will be published in GFZ data service as open access data

Present-day and projected future hydrological conditions across Peru

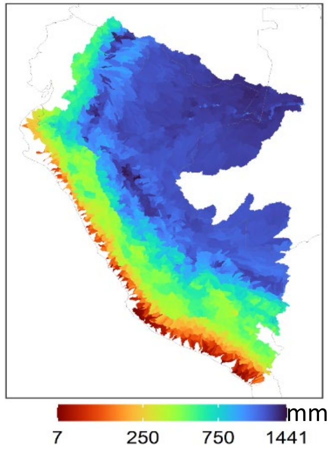
under sustainable pathway (SSP1-2.6) and Fossil-fueled development (SSP5-8.5)

Present-day conditions (1985-2015)

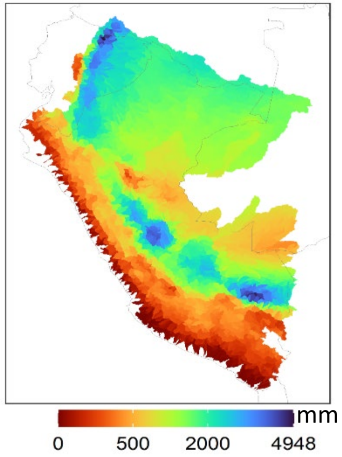
Precipitation



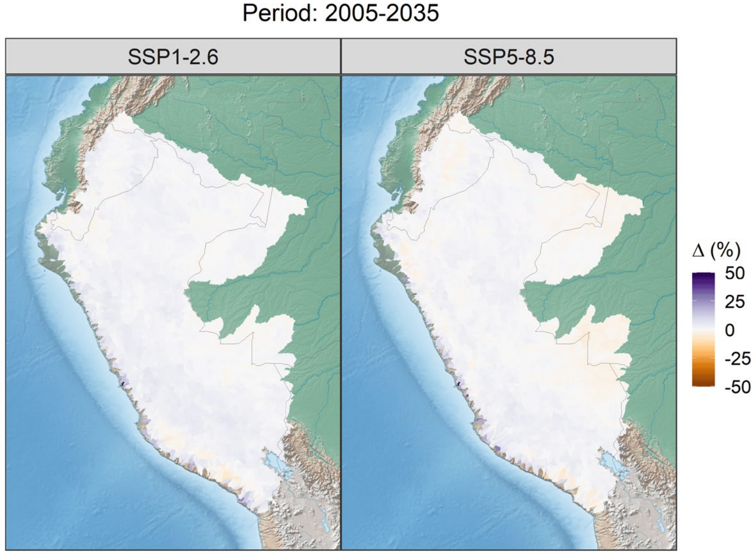
Evapotranspiration



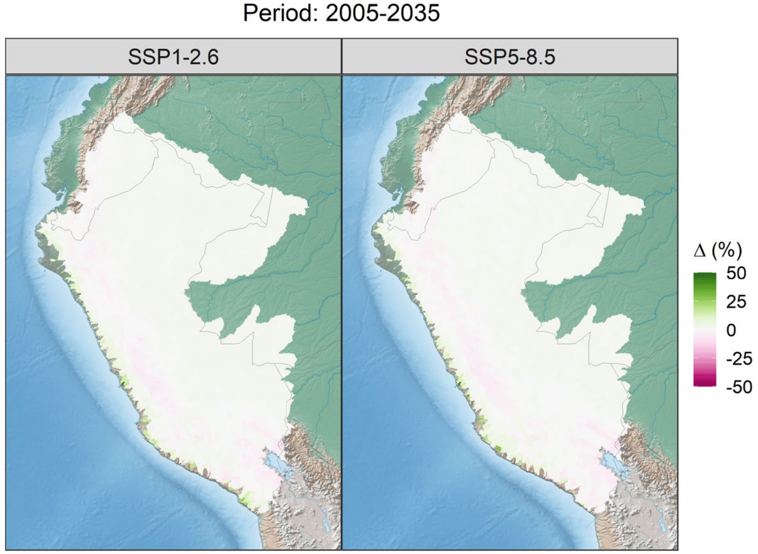
Water yield (water available)



Projected changes (1985-2015)

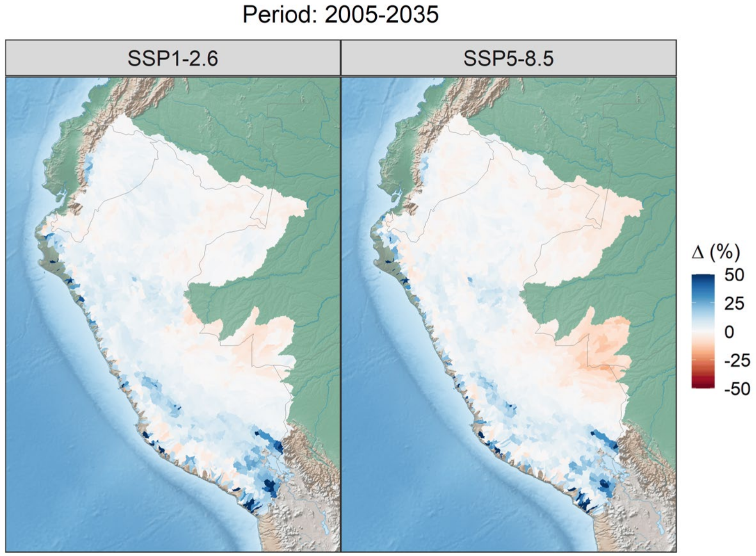


↓ P over lowlands (specially over the southern region)
↑ P along the Peruvian Andes



No changes in E over Andean basins

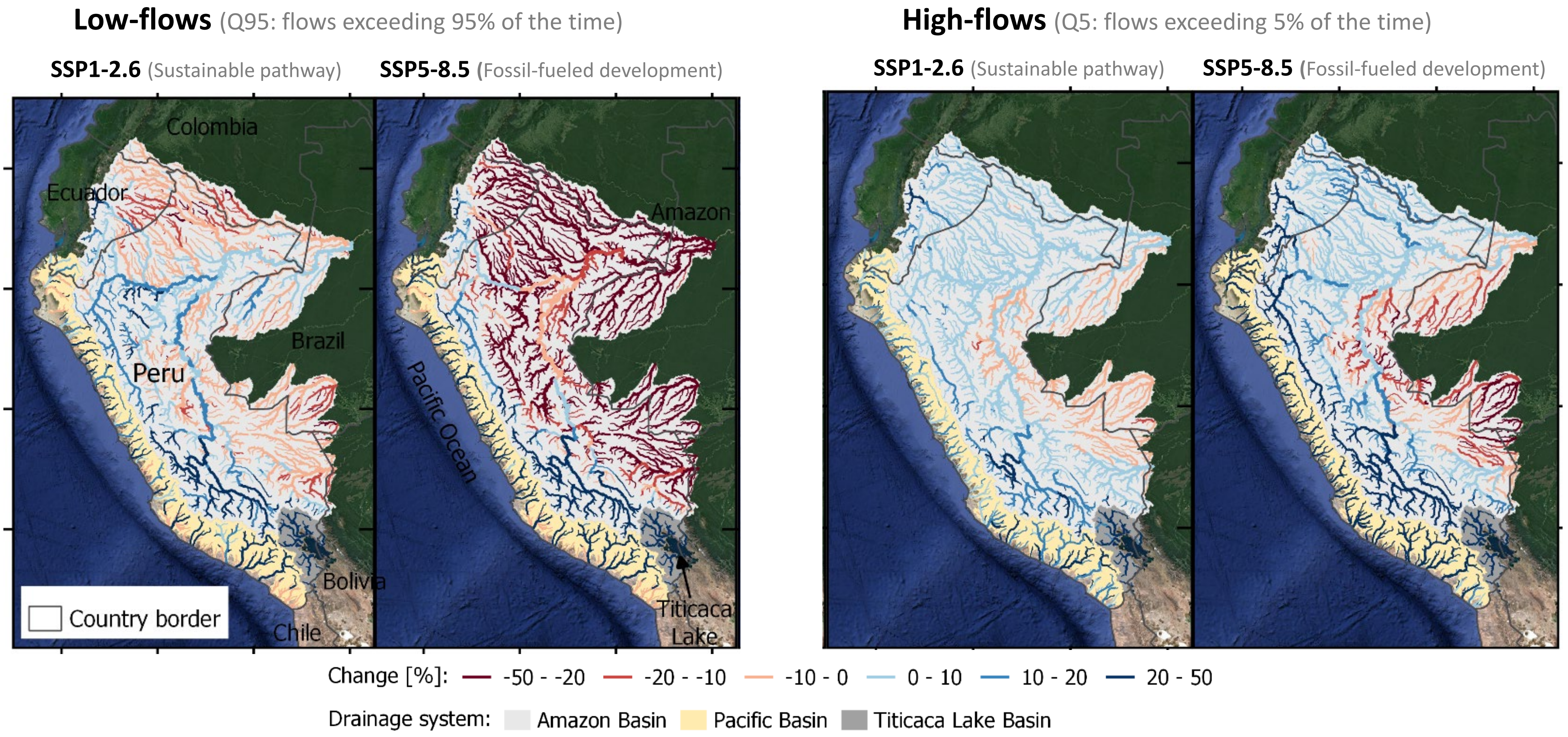
↑ E over the lowlands and arid coastal areas



↓ water yield over the lowlands, particularly in the southern region.
↑ water yield along the Andean basins

Projected changes in hydrological extremes

for the end of the century (2065-2095) relative to the baseline period (1985-2015)



↑ Increased low flow magnitude in Andean basins
↓ Decreased low flow magnitude in lowlands

↑ Andean and northern Amazon basins will experience intensified high flows
↓ Central and south lowlands will experience decreased high flows.

Conclusions

- The first country-wide water budget and climate change analysis conducted in Peru
- Future indications of decreased water availability over the lowlands and increased availability along the Andean basins.
- Peru may face intensified floods in the Andean catchments and water scarcity during droughts in the Amazon lowlands in the future.
- Future water resources management needs to account for these developments

THANKS