**RESEARCH ARTICLE**

Can ecPoint-Rainfall identify flash floods in Ecuador?

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**Abstract.**

**Keywords.**

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# Introduction

# Background: geography, rainfall climatology and flooding in Ecuador

Continental Ecuador is located in north-western South-America (see the small box in Figure 1a), between Peru and Colombia, within 1.60 °N - 3.50 °S and 81.10°W - 75.28 °W. Ecuador's Galapagos Islands, 1000 km to the west of continental Ecuador (see the small box in Figure 1a), are not included in this study. Therefore, "continental Ecuador" will be referred to simply as "Ecuador" from now on. Vuille, Bradley and Keimig (2000) showed that the Andes cordillera that runs from north to south across Ecuador creates three main geographical regions (see Figure 1a): "La Costa", i.e., the coastal plain next to the Pacific Ocean, which is mainly influenced by the sea surface temperature (SST) variations in the Pacific Ocean; "El Oriente", i.e., the Amazon region, which is primarily influenced by the strong convective activity across the Amazon forest and the water vapour variations from the SST of the tropical Atlantic Ocean; and "La Sierra", i.e., the Andean region between "La Costa" and "El Oriente", which is mainly influenced by the Intertropical Convergence Zone and incursions from the Amazon climate.

Tobar and Wyseure (2018) have found four distinct rainfall patterns in Ecuador, closely related to the three above-mentioned geographical regions. Two rainy seasons in "La Costa" occur mainly from late December through May, with the Pacific side of the Andes cordillera having a similar pattern than in the valleys but with more moderate seasonality. The rainy season in "La Sierra" runs from September to April/May, while it rains throughout the year in "El Oriente" with the wettest (driest) months being April-July (September-October). These results confirmed those mentioned by Recalde-Coronel, Barnston and Muñoz (2014), obtained in an unpublished study carried out by the main author. The extreme phases of El Niño Southern Oscillation (ENSO), known as El Niño (i.e., above-average SST in the Pacific Ocean) and La Niña (i.e., below-average SST), strongly modulate precipitation and temperature in "La Costa". During El Niño (La Niña) events, "La Costa" experiences higher (lower) than average rainfall events between February and April, strengthening the normal rainfall seasonality in the region (Tobar and Wyseure, 2018). ENSO's effect in rainfall variations gradually diminishes towards the west, concluding that the Andes cordillera acts as an eastward barrier for the impacts of ENSO in "La Sierra" and in "El Oriente" (Vuille, Bradley and Keimig, 2000; Recalde-Coronel, Barnston and Muñoz, 2014): "La Sierra" can experience below-normal precipitation due to an anomalous Hadley cell that inhibits convection over the Andes cordillera, while there is almost no correlation between rainfall variations and ENSO in "El Oriente".

The flooding in “La Costa” during El Niño events can cause considerable material loss and deaths, whereas La Niña can result in droughts which has slower acting but also potentially disastrous consequences.

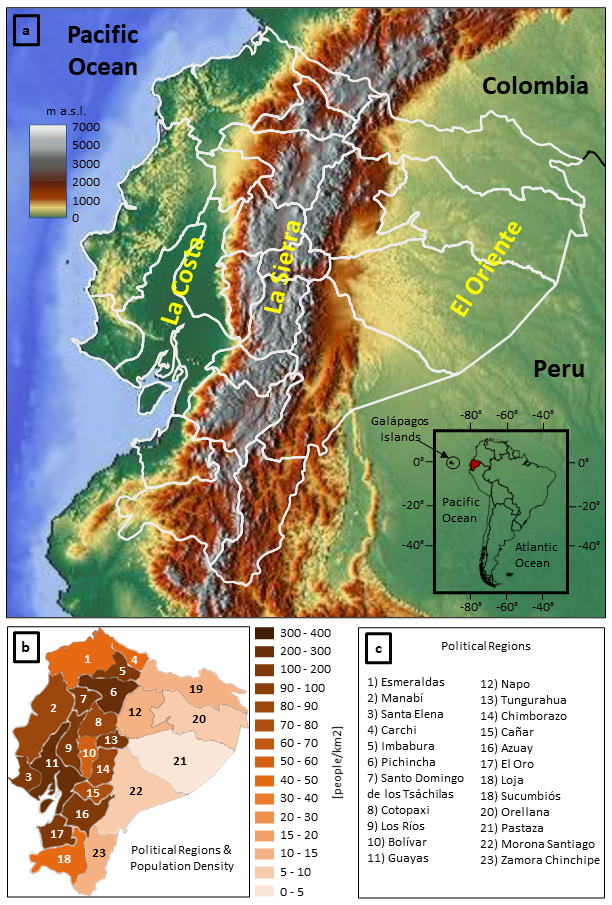


Figure 1 - Panel (a) shows Ecuador’s orography, its political regions, and the location of Ecuador’s three main geographical regions: the coast (“La Costa”), the highlands (“La Sierra”), and the Amazon (“EL Oriente”). The small box shows Ecuador’s location in South America. Panel (b) shows the population density (in people/km2) for each region from 2020 census (source: <https://es.wikipedia.org/wiki/Provincias_de_Ecuador>). Panel (c) lists the names of Ecuador’s political regions following the numbers indicated in panel (b).

# Data

## Forecasts: ecPoint-Rainfall and ECMWF ENS

## Benchmark dataset: flash flood reports in Ecuador

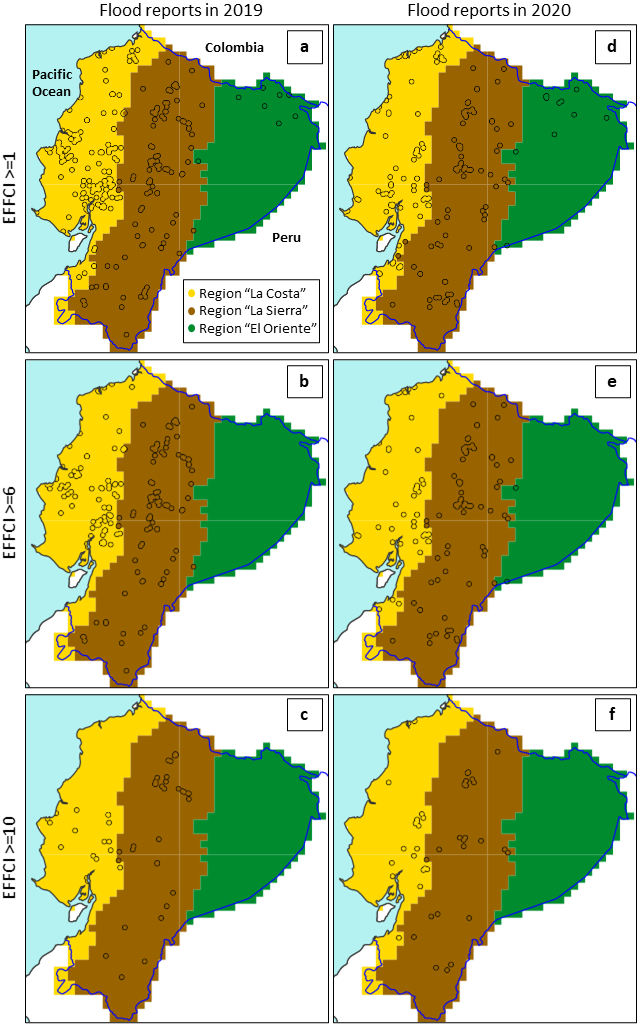


Figure 2 - Flood reports for 2019 (first column) and 2020 (second column) indicated by the black circles. The maps show flood reports with EFFCI>=1 (first row), an EFFCI>=6 (second row) and an EFFCI>=10 (third row).

# Methods

A rainfall event that might generate a flash flood is defined as that event that exceeds a predetermined “trigger” rainfall threshold.

The Relative Operating Characteristic (ROC) curve is used to analyse whether ecPoint-Rainfall is able to improve the detection of flash floods in Ecuador at medium-range lead times, compared to the ECMWF rainfall ensemble forecasts (ENS). This analysis assesses the skill of the probability forecasts of exceeding the thresholds. For any event, a ROC curve can be constructed to provide information on the hit rates and false alarm rates that can be expected from the use of different probability thresholds to trigger advisory action.

In the absence of a dense network of rainfall observations needed to assess the magnitude of localized rainfall extremes in small regions, i.e. one country, and in a limited period of time, i.e. only one year verification period (Haiden and Duffy, 2016), the rainfall values associated with flash flood events in Ecuador were determined from day 1 ecPoint-Rainfall forecasts. Day one ecPoint-Rainfall forecasts are considered the nearest equivalent to rainfall observations, and their 99 percentiles are considered representative of the rainfall variability within the grid-box that contains the flash flood reports (Hewson and Pillosu, 2021). This last aspect provides an important advantage over the use of “real” observations that, by chance, might or not capture the extreme rainfall value that generated the flash flood (Hewson and Pillosu, 2021).

How ecPoint-Rainfall is capable to identify flash floods was analysed by creating Definition of rainfall thresholds

* For each flash flood report, extract all the percentiles of day1 ecPoint/Rainfall forecasts. Such forecasts are considered to represent the rainfall sub-grid variability within the grid-box.
* Two rainfall periods can overlap with each flash flood report, which means there will be 198 realizations for each flash flood report. The time given for each flash flood report represents the time of the flash flood occurrence and it is given in local time. Flash flood reports with not time were not considered in the analysis. For the calibration dataset (i.e. flash flood reports in 2019), only 3 reports over 302 had not associated time. For the verification dataset (i.e. flash flood reports in 2020), no reports had not associated time.
* We pull together all the 198 X n realizations (where n corresponds to the number of flash flood reports in the calibration dataset) and compute percentiles that will function as rainfall thresholds for the verification.
* Subsequently, the n reports in the calibration dataset are separated in the three main Ecuador regions (i.e. Costa, Sierra and Selva), and the percentiles are re-computed again for each region.

## Verification of ecPoint-Rainfall forecasts

* A sensitivity analysis is carried out to identify which percentile functions better as threshold to detect flash floods in Ecuador.

# Results

# Discussions

* The verification method needs to consider that the flash flood reports are not collected everywhere.

# Conclusions

# References

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