

Climate change and deforestation in Haiti: are historical hydro-meteorological observations relevant to describe present catchment hydrological characteristics?

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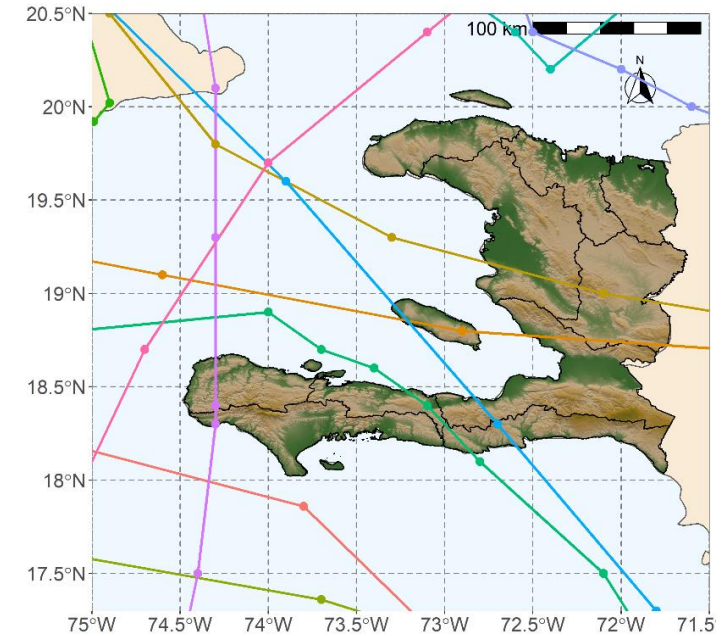
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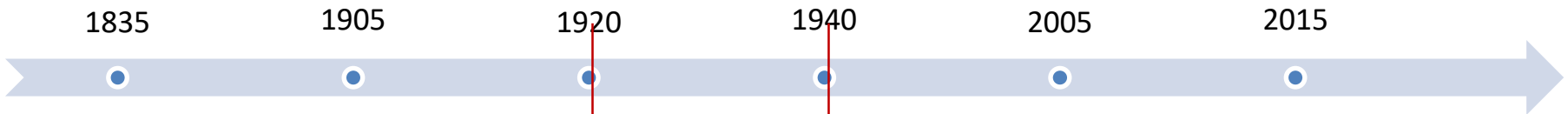
Context and objectives of this work

- ❖ Haiti → in hurricane's path + intense floods → **highly exposed to hydrometeorological hazards.**
- ❖ Haitian cities : in flood plains + weak economic situation → **high vulnerability to these hazards.**
- ❖ Haiti: currently ungauged country (*both in terms of rainfall and streamflow*) → **none hydrological references about high rainfall and floods.**
- ❖ 1920-1940: two decades of continuous time series of both rainfall and streamflow → **estimate catchment hydrological characteristics over this historical period**
- ❖ Climate change + massive deforestation → **Are 1920-1940 characteristics relevant to describe present catchment hydrological characteristics?**



<https://haiti.loopnews.com/content/la-ville-des-cayes-sous-les-eaux-apres-deux-jours-de-pluie>

Data used



Digitization of 70 daily flow gauging stations

156 monthly rainfall series 1905 - 2005 (Moron *et al.* 2015)

Daily rainfall gridded at 1° ≈ 111 km. NOAA 20th Century Reanalysis (Slivinsky *et al.* 2019)

Daily temperature gridded at 1° ≈ 111 km. NOAA 20th Century Reanalysis (Slivinsky *et al.* 2019)

Concomitant period of data availability

 Monthly time step
 Daily time step



NASA SRTM V3 Global 1 arc second DEM (Reuter *et al.* 2007)

Methods: data processing

Daily flows series processing



Remove series < 120 months



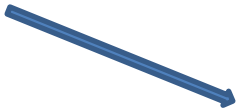
Test the correlation between neighboring series



Remove doubtful series



Define catchments of remaining series



NOAA gridded daily rainfall



Daily rainfall at catchment scale



Monthly rainfall at catchment scale



Daily NOAA rainfall time series corrected using monthly rainfall amount at the catchment scale

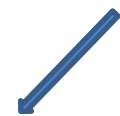
Monthly rainfall series processing



Remove series < 220 months



Thiessen polygons



Methods: catchment characteristics and rainfall-runoff modeling

❖ Catchment water balance with Turc-Budyko graphic (Coron *et al.* 2015).

- Mean of Q , P and PE over 1920-1940
- Plot $Q/P = f(P/PE)$

❖ Calibration of GR4J for each catchment:

- Mean latitude + temperature \Rightarrow PE
- (Oudin *et al.* 2005)
- 1920 - 1921 \Rightarrow warm-up
- 1922 – 1940 \Rightarrow calibration
- Objective function : $KGE(Q)$

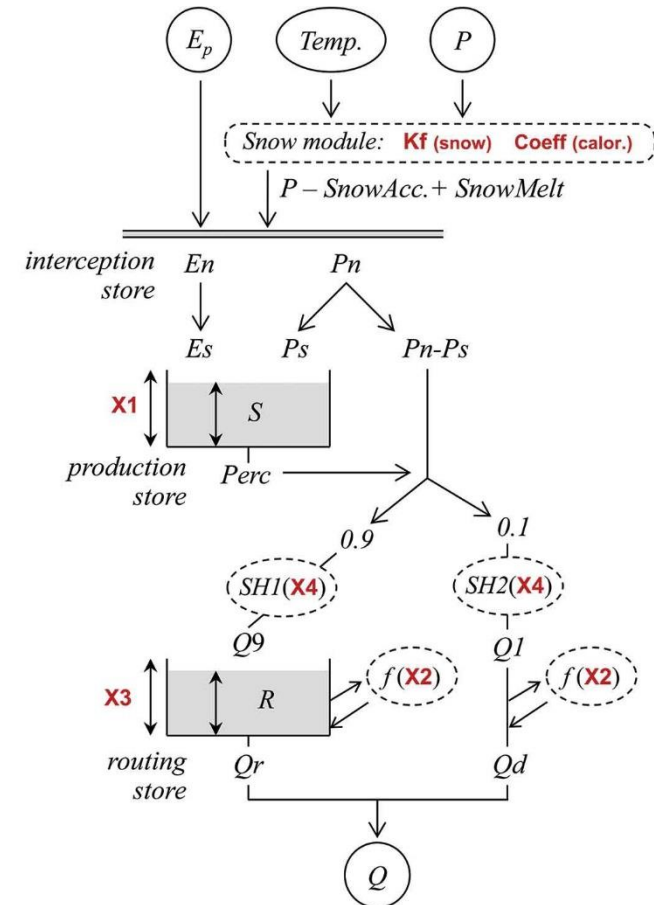
❖ GR4J performance over high flows

- 99th percentile (Q_{99}) ratio of Q_{cal} VS Q_{obs}

❖ Evaluate high flow sensitivity to:

- “Climate change”: here high precipitation changes
- “Deforestation”: here one parameter of GR4J ($X1$)

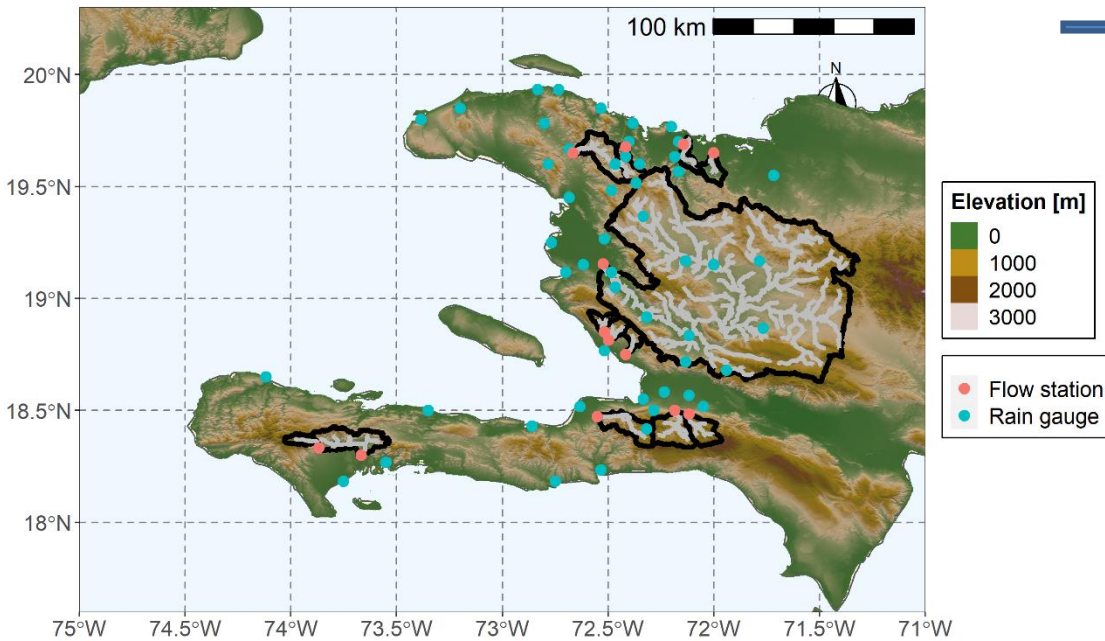
GR4J presentation (Perrin *et al.* 2003)



Parameters

| | | |
|----------------|---|-------------|
| $X1$ | production store capacity | [mm] |
| $X2$ | groundwater exchange coefficient | [mm/d] |
| $X3$ | routing store capacity | [mm] |
| $X4$ | unit hydrograph time constant | [d] |
| K_f (snow) | degree-day melt coefficient | [mm/degC/d] |
| Coeff (calor.) | weighting coefficient for snow pack thermal state | [-] |

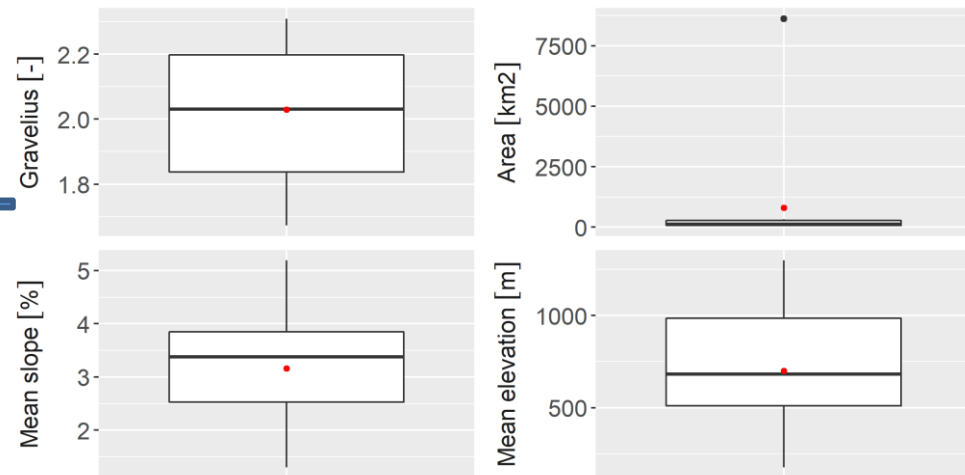
Results: catchment set



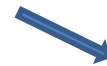
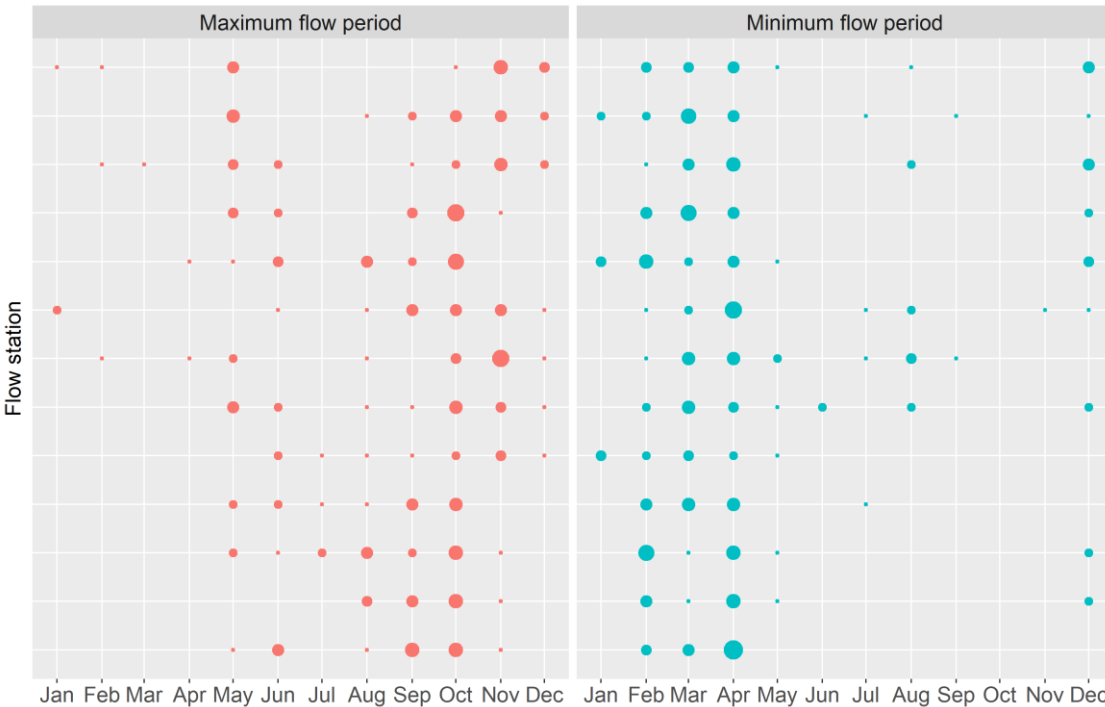
- ❖ 13 daily flow time series are used
- ↓
- ❖ 13 associated catchment
- +
- ❖ 53 monthly rainfall used to reduce bias of daily NOAA rainfall time series

Catchment characteristics

- ❖ Elongated catchments (Gravelius ≈ 2)
- ❖ Catchment with steep slopes
- ❖ Small catchments (median area $\approx 130 \text{ km}^2$)



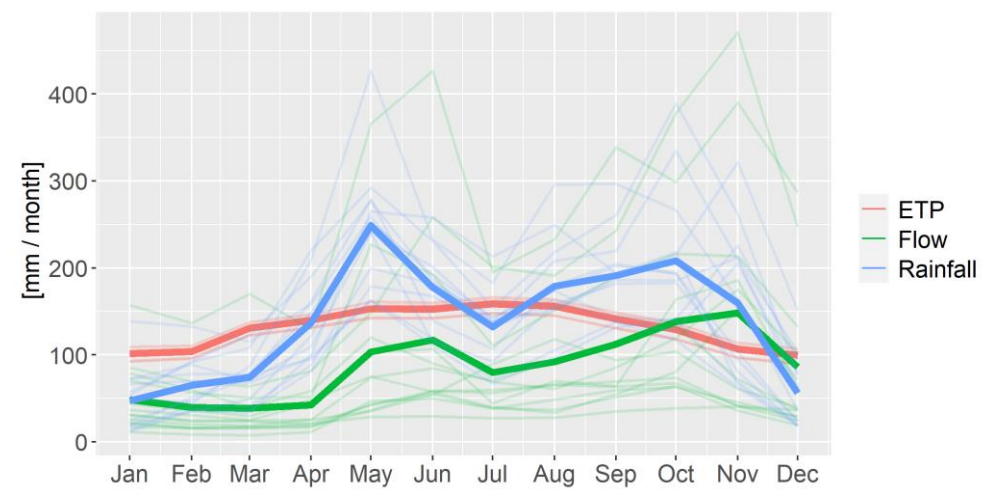
Results: catchment hydro-climatic characteristics



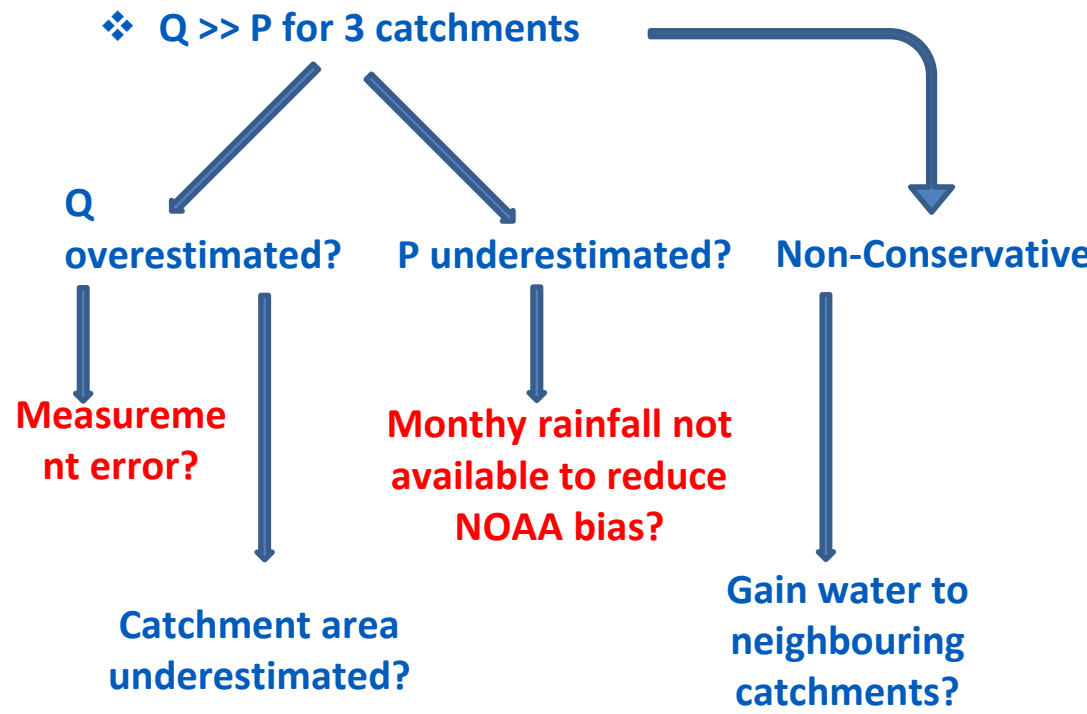
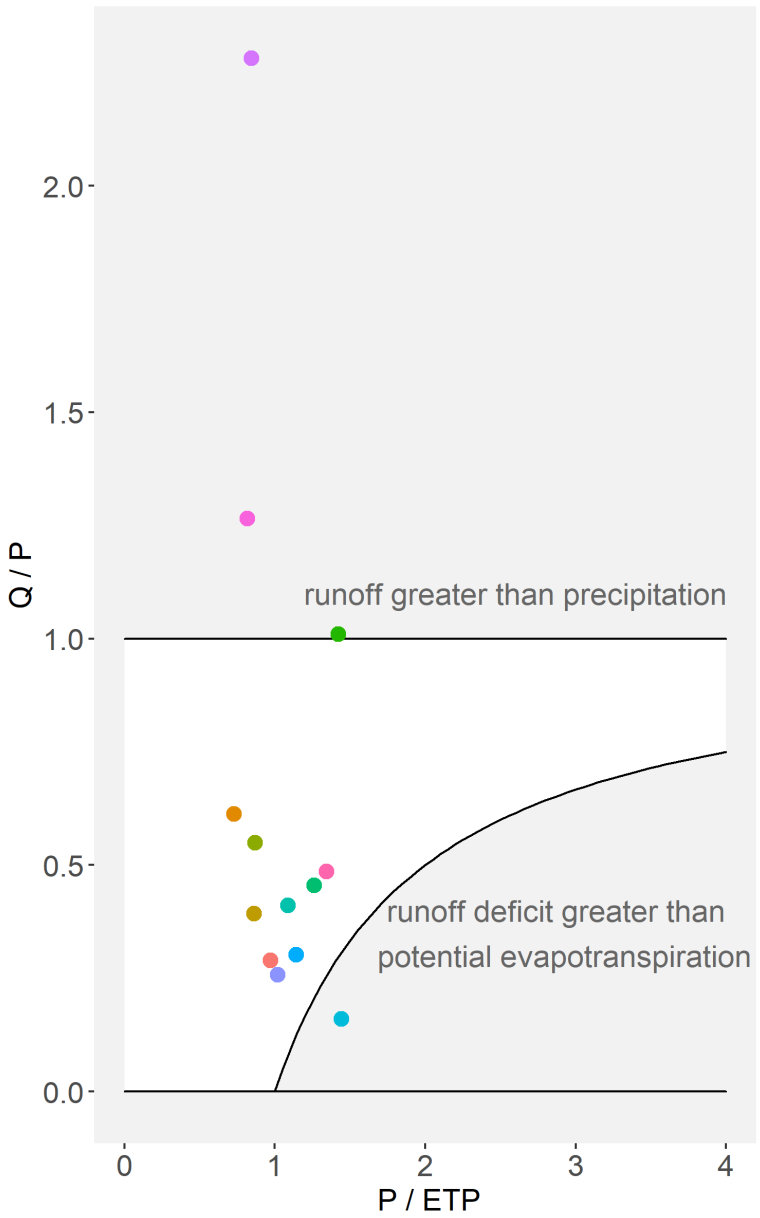
- ❖ Maximum flow occurs mainly during the hurricane season.
- ❖ Minimum flow occurs from December to April.

Catchment regimes

- ❖ Two rainfall peaks (May + hurricane season)
- ❖ Winter + July \Rightarrow $PE > P \Rightarrow$ less flow
- ❖ Tropical region \Rightarrow rain controls flow



Results : catchment water balance

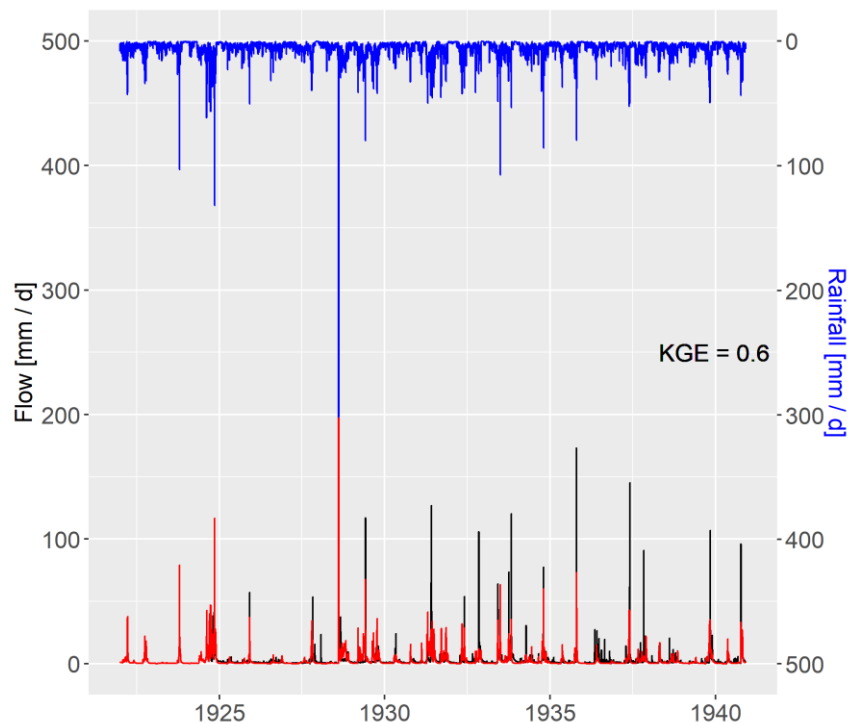


❖ $ETR > ETP$ for 1 catchment:

- Underestimation of PE ?
- Overestimation of P?
- Underestimation of Q?
- Lose water to neighbouring catchments?

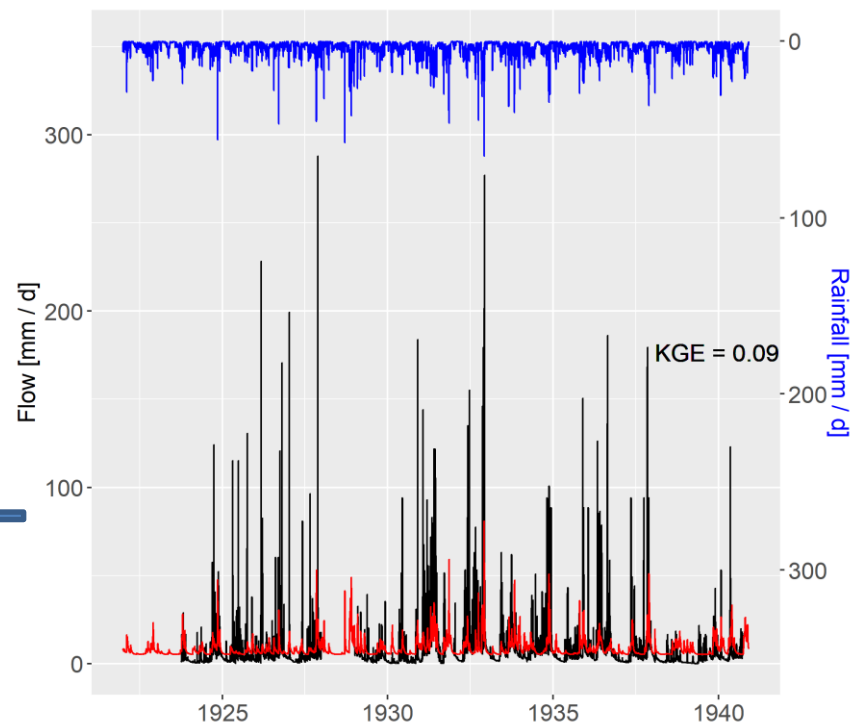
Results: model calibration on two catchments

Catchment with good performance:



- ❖ Good overall performances of GR4J
- ❖ Limited performance on high flows?

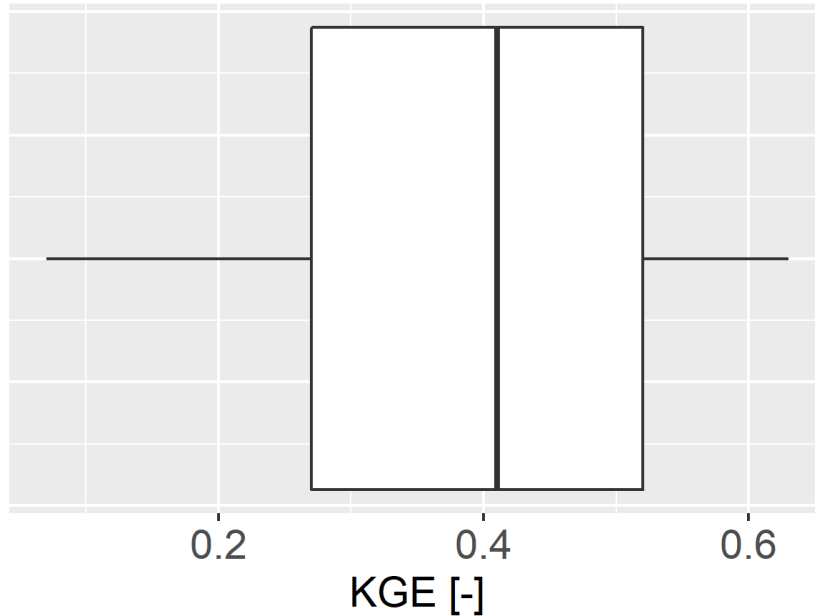
Catchment with bad performance:



- ❖ P underestimated?
- ❖ Q overestimated or underestimated area ?

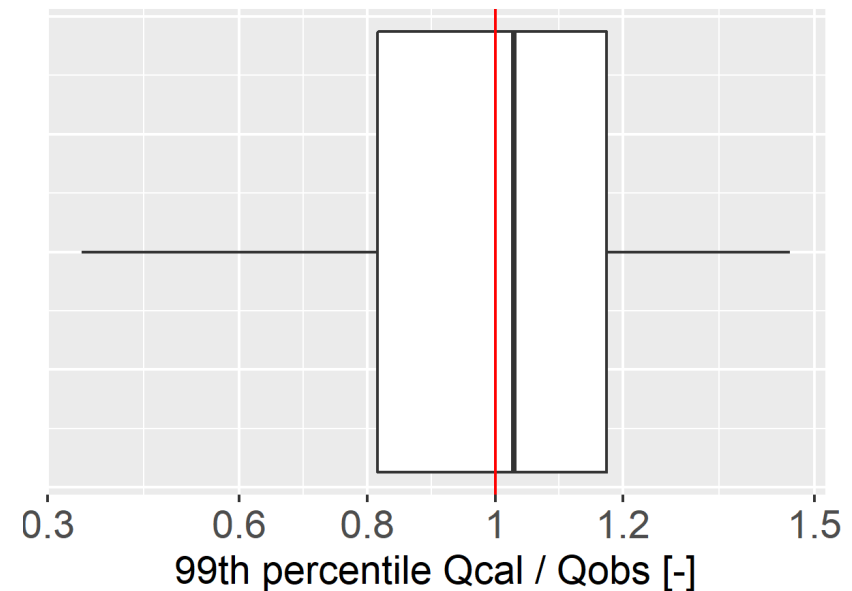
Results: general performance on all catchments

All catchments



- ❖ KGE over half catchments < 0.4
- ❖ Problematic input data ? **Especially P ?**
- ❖ GR4J is not performing well in this study area ?

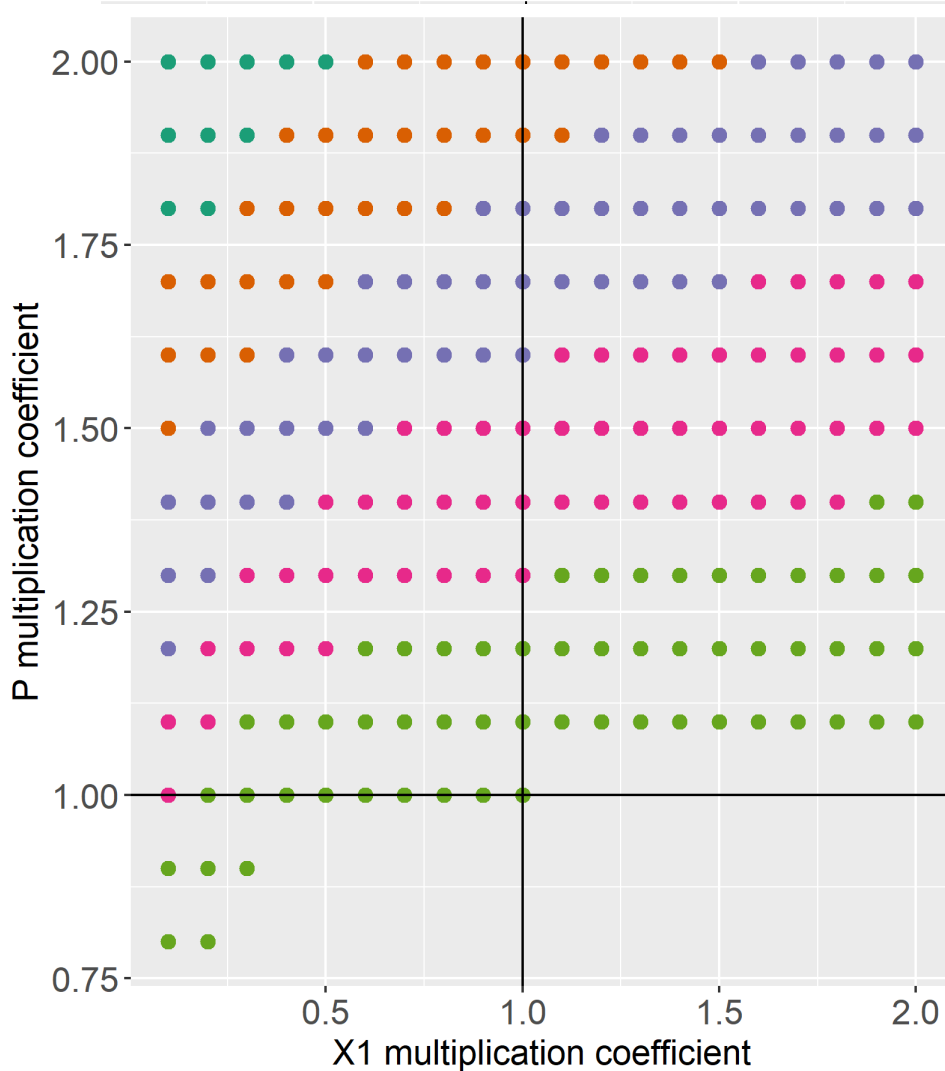
Ratio of high flows



- ❖ Ratio near to 1 for most catchments
- ❖ GR4J is able to simulate high flows

Results: high flows sensitivity to changes

Most sensitive catchment:



❖ Anthropogenic change sensitivity

$0.1 * X1$ \Rightarrow runoff coefficient
increase \Rightarrow $3.1 * Q99$

Explicit relation between $X1$
and runoff coefficient ?

❖ Climate change sensitivity

$2 * P99$ \Rightarrow more intense heavy
rainfall \Rightarrow $5.2 * Q99$

Conclusion

- ❖ First analysis of historical flow and rainfall data over Haiti
- ❖ Obtained hydroclimatic regimes and characteristics are coherent with known regional characteristics
- ❖ GR4J gives promising results on the catchment set, and can be used to characterize high flows in the Haitian catchments.
- ❖ First sensitivity test to illustrate the flood changes induced by both climatic and « land-cover » changes:

Perspectives

- ❖ Using catchment analysis and model performances to improve the hydroclimatic database by correcting errors
- ❖ Quantifying deforestation of the Haitian catchment (Haiti has less than 1% of its original primary forest. Hedges et al. 2018)
- ❖ Exploring the relationship between the runoff coefficient and rainfall-runoff model parameters

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