Web-based CHIRPS bias correction tool to improve hydrological simulation in SWAT

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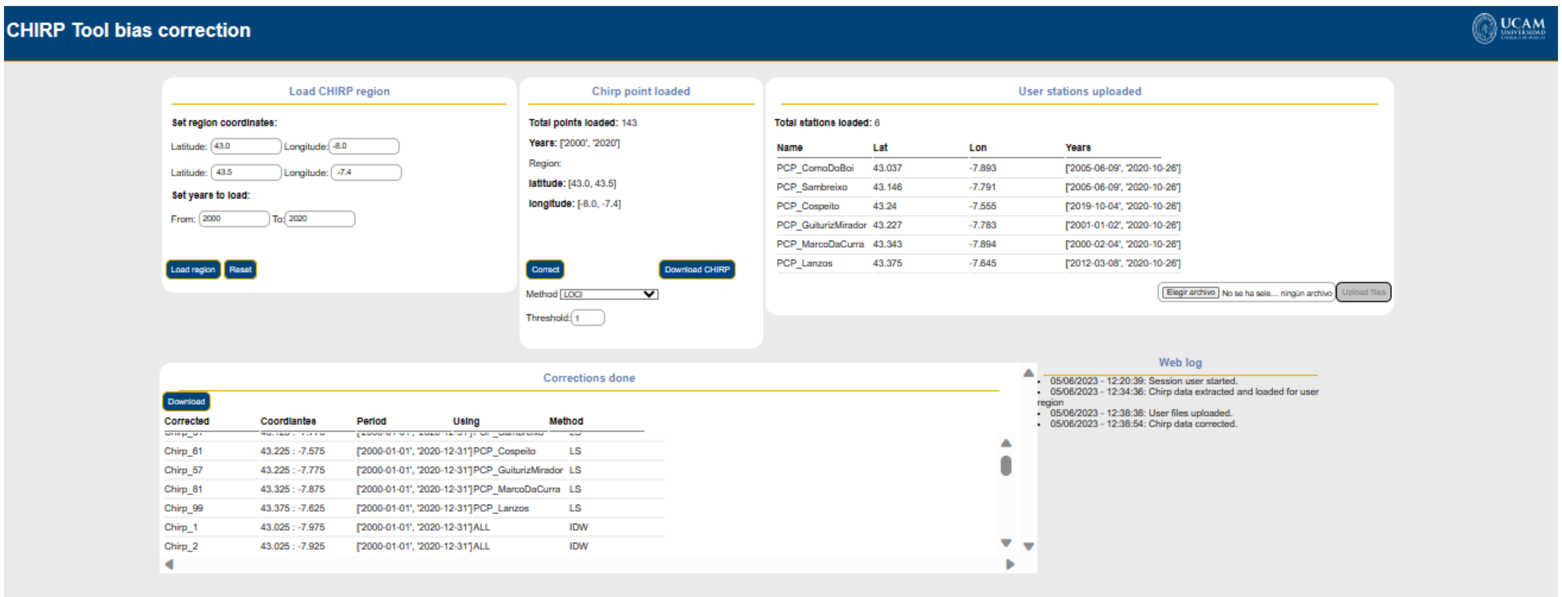

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Soil & Water Assessment Tool SWAT

Outline

- Introduction: Scientifical Context and Objectives.
- Methodology
  - CHIRPS data-set
  - Rain gauge stations
  - Bias-correction techniques
- Study Case
  - Results
  - Discussion
- Conclusions.

Scientifical Context

- **Rainfall data are crucial** in the application of hydrological models such as the Soil and Water Assessment Tool (SWAT).

- Conventional **ground-based gauge stations** are the sources of rainfall measurement data.

- Their **spatial and temporal distribution** will determine the reliability in replicating the different processes in water cycle**.**
    - Historical records are unsuitable
    - Contain missing values (technical failures)
    - Inadequate spatial coverage.

Introduction
Scientifical context
Objectives
Methodology
Study case
Conclusions

Scientifical Context

- In the last decades, **open-access satellite precipitation products** have become a potential tool to overcome these constraints.
- Examples: Tropical Rainfall Measuring Mission (**TRMM**) Multisatellite Precipitation Analysis (**TMPA**), Climate Prediction Center (CPC) morphing technique (**CMORPH**), Precipitation from Remotely Sensed Information using Artificial Neural Networks (**PERSIANN**) or Climate Hazards Group (CHG) InfraRed Precipitation (CHIRP) and combined with stations observations (**CHIRPS**).
- **CHIRPS has proved to be a good alternative input** for the **SWAT model** to predict the streamflow in diverse climatic conditions (Dhanesh et al., 2020)

Introduction
Scientifical context
Objectives
Methodology
Study case
Conclusions

Scientifical Context

- Satellite rainfall estimation algorithms are extensively being explored to produce **reliable and accurate estimates** meaningful for hydrological assessments.

- Evaluation studies show that **estimates are subjected to systematic and random errors** (Fuka et al. 2014; Bhatti et al. 2016)

- **The systematic error (bias) should be removed** before the products can be used for hydrological and water resources applications.

Introduction
Scientifical context
Objectives
Methodology
Study case
Conclusions

Objectives

- Provide a **web-based tool** to easily download CHIRPS grid data in a region in SWAT format (both raw and corrected).
- Choice and assessment of different **bias-correction techniques** using existing rainfall gauge station datasets .
- Performance the **hydrological models in SWAT** with different grids in order to analyse the results.
- **Comparison of the statistics** computed using the **bias-correction grid data over raw dataset** in a streamflow simulation.

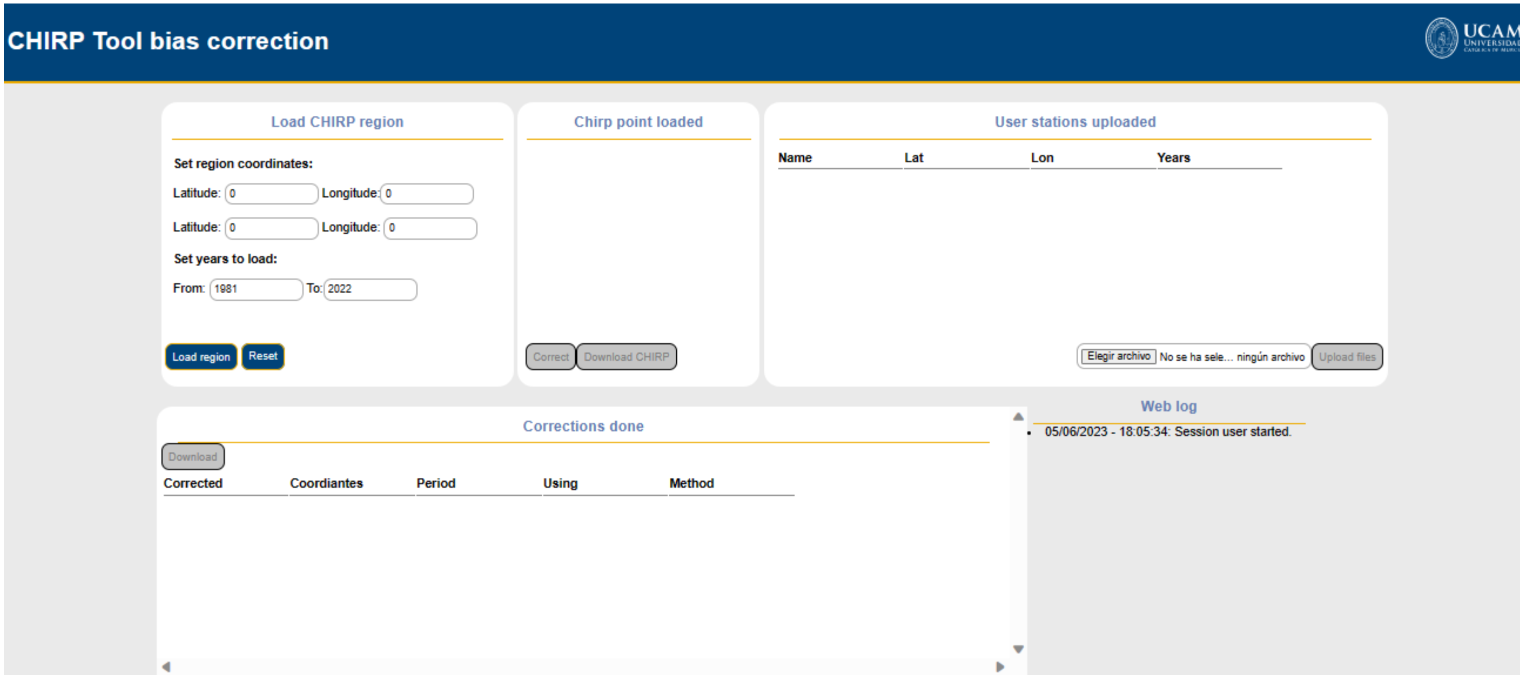
Introduction
Methodology
Step 1
Step 2
Step 3
Step 4
Study case
Conclusions

CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data)

- **35+ year** quasi-global (50ºN-50ºS) rainfall dataset of **0.05º spatial resolution** (time series of gridded rainfall).
- It incorporates Climate Hazards Group Rainfall Climatology (**CHP Clim**), geostationary thermal infrared satellite observations, Tropical Rainfall Measuring Mission (**TRMM**), atmospheric model rainfall fields from **NOAA Climate Forecast** System and **rainfall observations** from national or regional meteorological sources.
- The dataset is available **open-source**.
- Period **1981-near present**.
- **http://chg.geog.ucsb.edu/data/chirps/**

Introduction
Methodology
Step 1
Step 2
Step 3
Step 4
Study case
Conclusions

http://facu.ucam.edu:8080/



•Programming language: Python 3.8.

•Libraries: Web: Flask>=2.2.2, Werkzeug>=2.2.2; CHIRPS datasets: geopy==2.0.0, matriz==0.2.7, netCDF4==1.6.3, numpy==1.17.4, pandas==1.1.2, scipy==1.5.2, xarray==0.17.0; Others: python_dateutil==2.8.2, seaborn>=0.11.1; pydeck>=0.6.1, chardet==5.1.0

Introduction
Methodology
Step 1
Step 2
Step 3
Step 4
Study case
Conclusions

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```
1 usage  gbequer@gmail.com <gbequer@gmail.com> *
def calculate_b_factor(self, serie):
    months = pd.DataFrame(
        {'count': self.observed_adjusted[self.parameter].groupby(self.observed_adjusted.index.month).count(),
         'count_raw': serie[self.parameter].groupby(serie.index.month).count()})
    # Solo hace falta CV_obs. lo demas se añade para control.
    for actual in range(1, 13):
        pre = (actual - 1) % 12
        post = (actual + 1) % 12

        pre = 12 if (pre == 0) else pre
        post = 12 if (post == 0) else post

        months.at[actual, "mean_raw"] = \
        serie[(serie['month'] == actual) | (serie['month'] == pre) | (serie['month'] == post)][
            self.parameter].mean()
        months.at[actual, "std_raw"] = \
        serie[(serie['month'] == actual) | (serie['month'] == pre) | (serie['month'] == post)][self.parameter].std()
        months.at[actual, "mean_obs"] = self.observed_adjusted[
            (self.observed_adjusted.index.month == actual) | (self.observed_adjusted.index.month == pre) | (
                        self.observed_adjusted.index.month == post)][self.parameter].mean()
        months.at[actual, "std_obs"] = self.observed_adjusted[
            (self.observed_adjusted.index.month == actual) | (self.observed_adjusted.index.month == pre) | (
                        self.observed_adjusted.index.month == post)][self.parameter].std()

    months['CV_obs'] = months['std_obs'] / months['mean_obs']
    months['CV_raw'] = months['std_raw'] / months['mean_raw']

    gbequer@gmail.com <gbequer@gmail.com> *
    def b_function_1(b, serie, cv_obs):
        return (cv_obs - (np.std(np.power(serie, b)) / np.mean(np.power(serie, b), dtype=np.float64)))
```

Introduction

Methodology

Step 1

Step 2

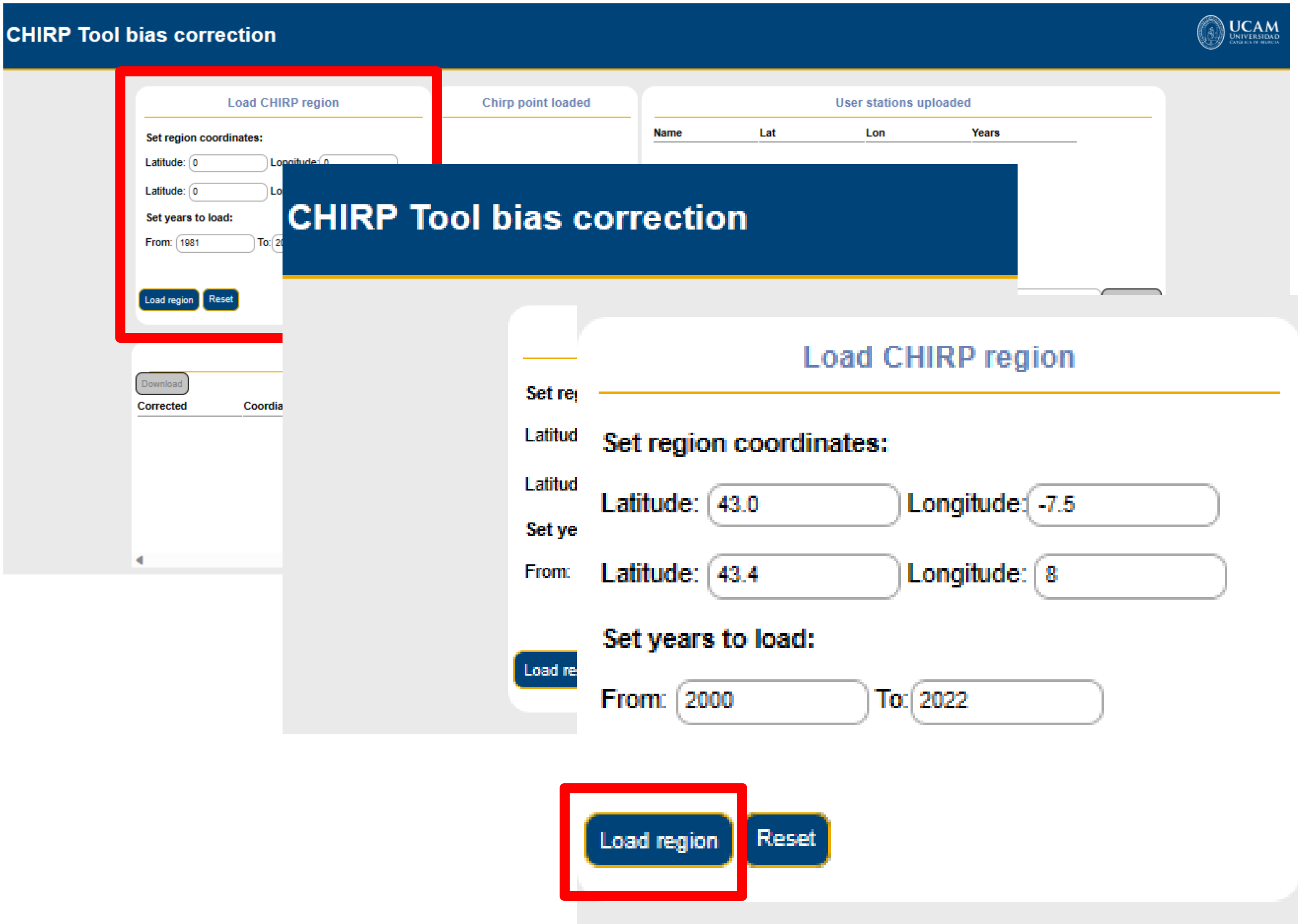
Step 3

Step 4

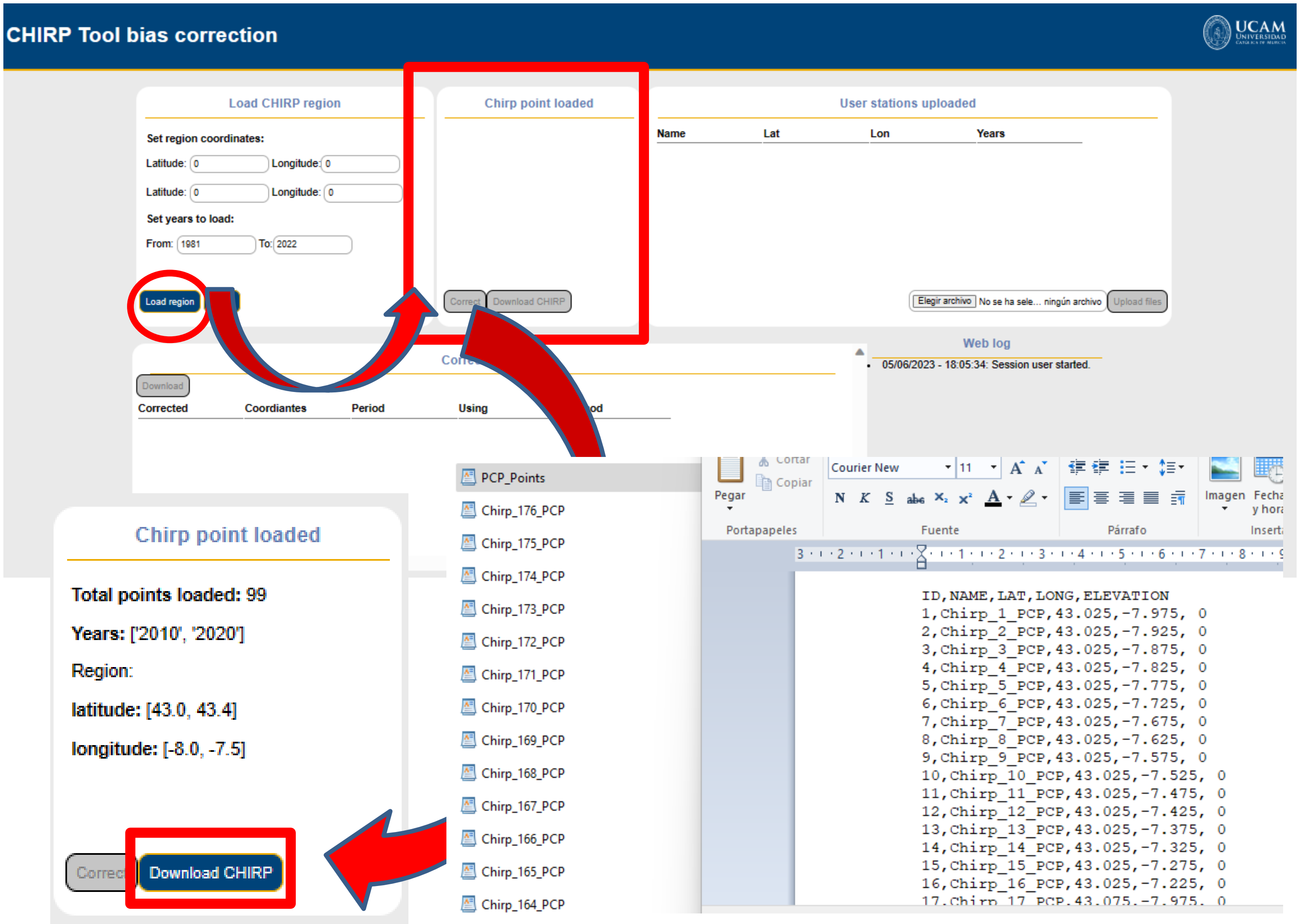
Study case

Conclusions

Step 1: Load CHIRPS region

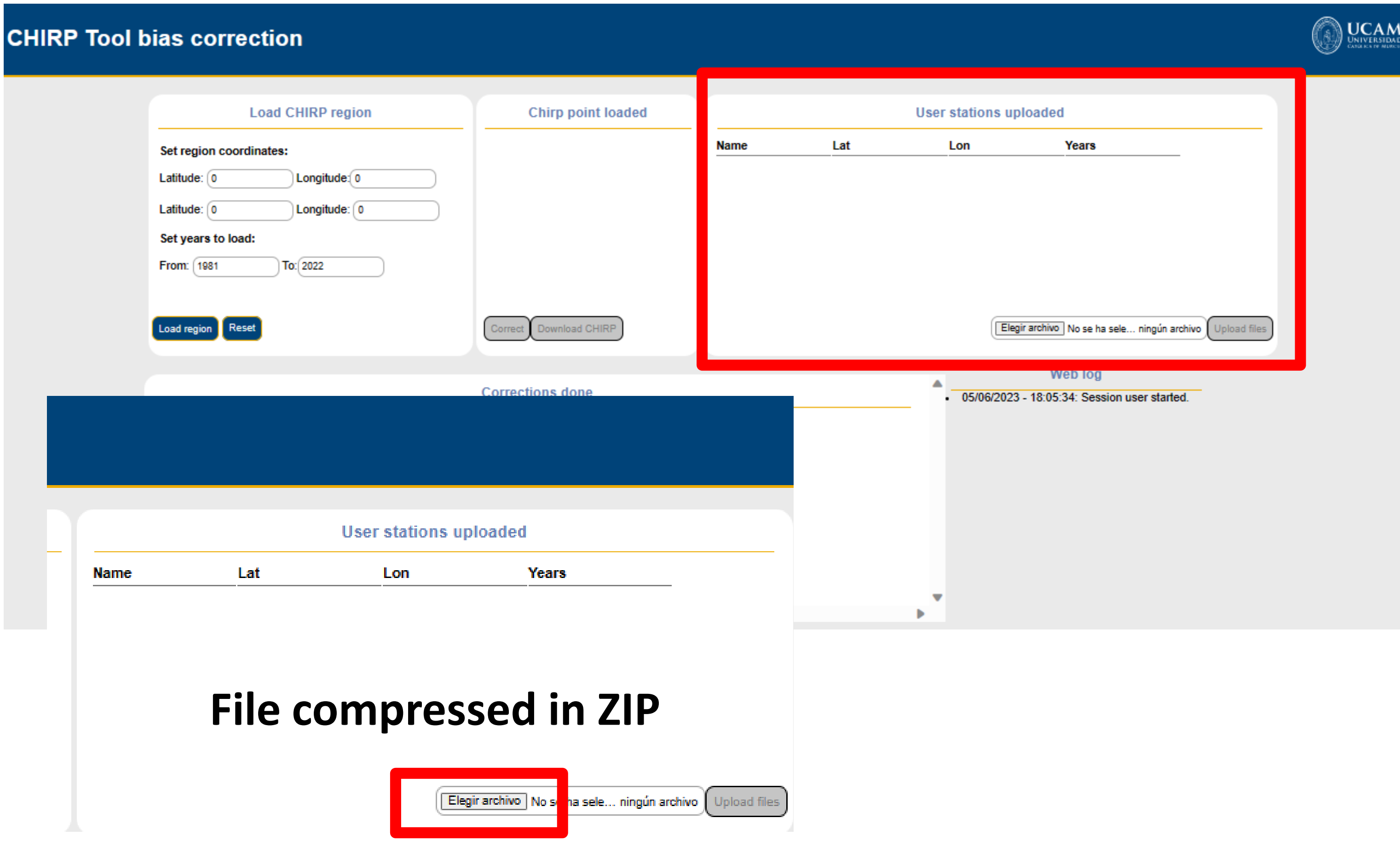


Step 1: Load CHIRPS region



Introduction
Methodology
Step 1
Step 2
Step 3
Step 4
Study case
Conclusions

Step 2: Upload rain gauge station data



Introduction

Methodology

Step 1

Step 2

Step 3

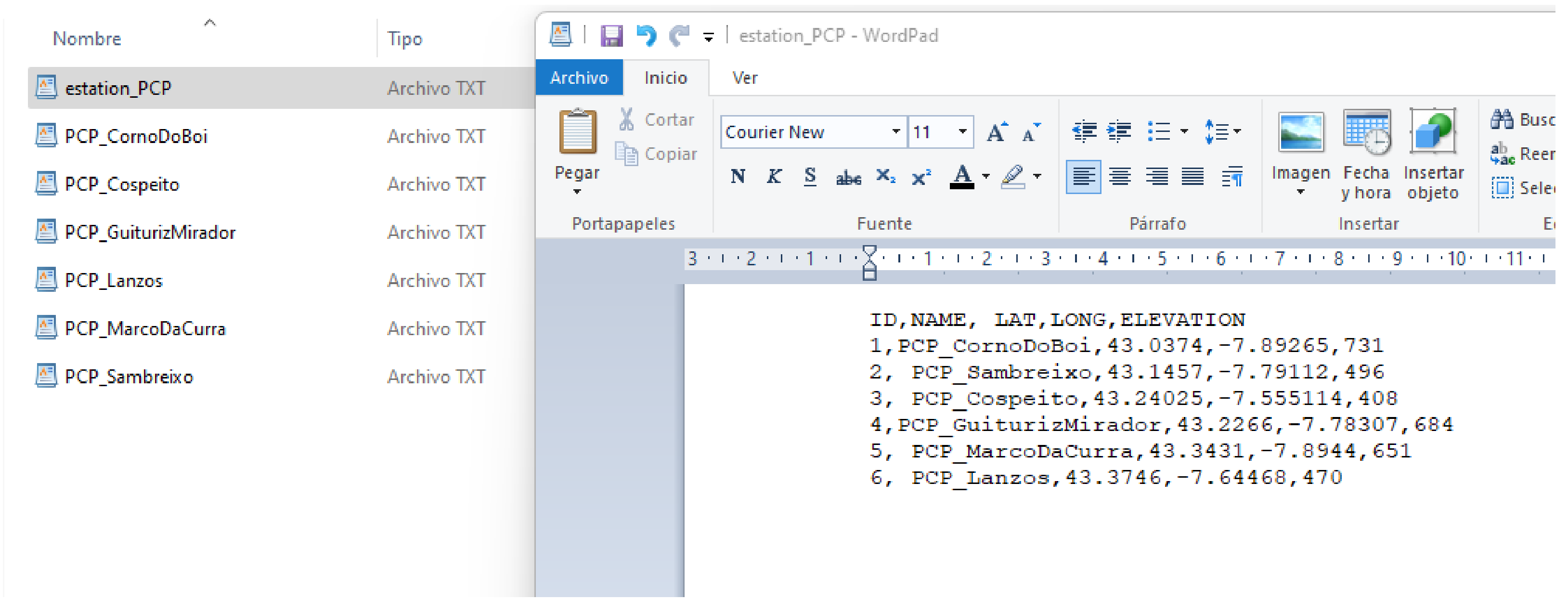
Step 4

Study case

Conclusions

Step 2: Upload rain gauge station data

- **File compressed in ZIP**



Step 2: Upload rain gauge station data

Introduction

Methodology

Step 1

Step 2

Step 3

Step 4

Study case

Conclusions

User stations uploaded

Total stations loaded: 6

Name	Lat	Lon	Years
PCP_CornoDoBoi	43.037	-7.893	['2005-06-09', '2020-10-26']
PCP_Sambreixo	43.146	-7.791	['2005-06-09', '2020-10-26']
PCP_Cospeito	43.24	-7.555	['2019-10-04', '2020-10-26']
PCP_GuiturizMirador	43.227	-7.783	['2001-01-02', '2020-10-26']
PCP_MarcoDaCurra	43.343	-7.894	['2000-02-04', '2020-10-26']
PCP_Lanzos	43.375	-7.645	['2012-03-08', '2020-10-26']

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Introduction

Methodology

Step 1

Step 2

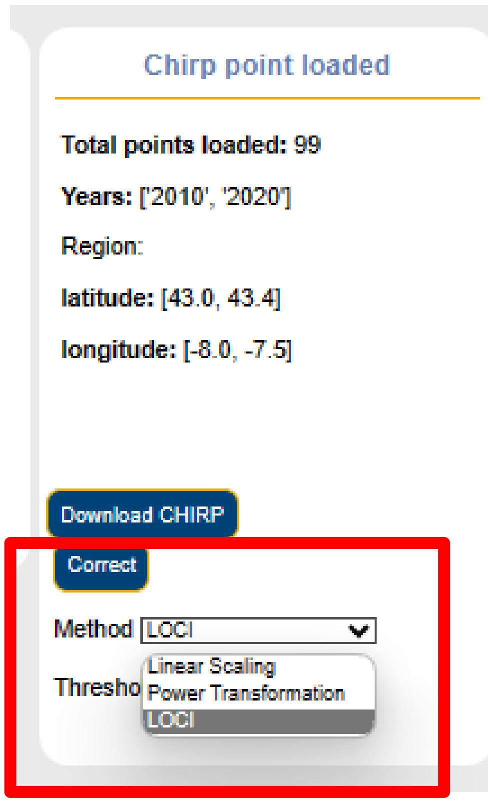
Step 3

Step 4

Study case

Conclusions

Step 3: Bias correction



- **Linear scaling (LS):**

$$P_{cor,m,d} = P_{raw,m,d} \cdot \frac{\mu(P_{obs,m})}{\mu(P_{raw,m})}$$

- **Local intensity scaling (LOCI):**

$$P_{cor,m,d} = \begin{cases} 0 & \text{if } \mathrm{P}_{\mathrm{raw,m,d}} < \mathrm{P}_{\mathrm{thres,m}} \\ P_{raw,m,d} \cdot S_m & \text{otherwise} \end{cases}$$

$$S_m = \frac{\mu(P_{obs,m,d} | P_{obs,m,d} > 0)}{\mu(P_{raw,m,d} | P_{raw,m,d} > P_{thres,m})}$$

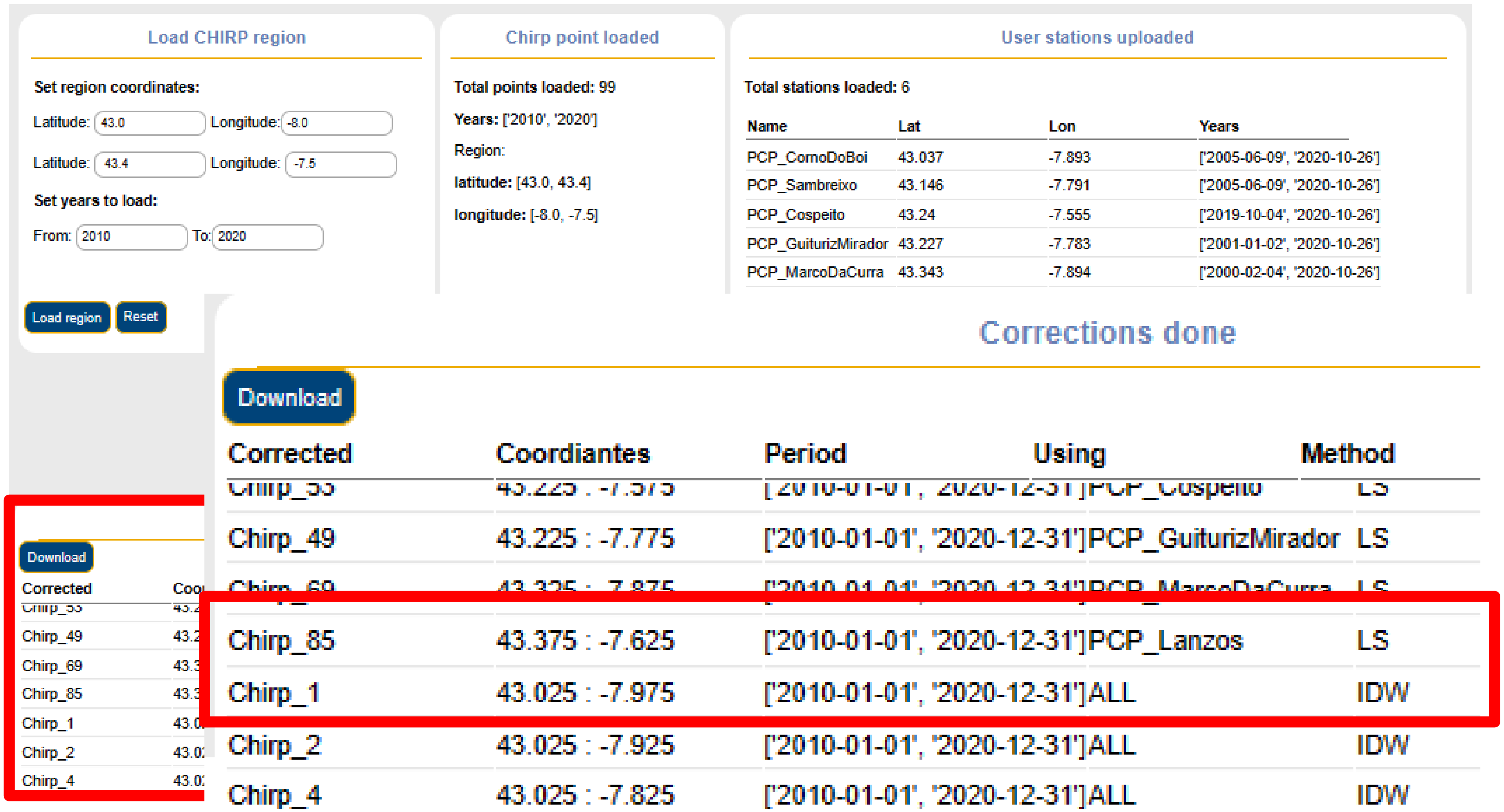
- **Power transformation (PT):**

$$P_{cor,m,d} = s_m \cdot P_{LOCI,m,d}^{b_m}$$

$$s_m = \frac{\mu(P_{obs,m})}{\mu(P_{LOCI,m}^{b_m})}$$

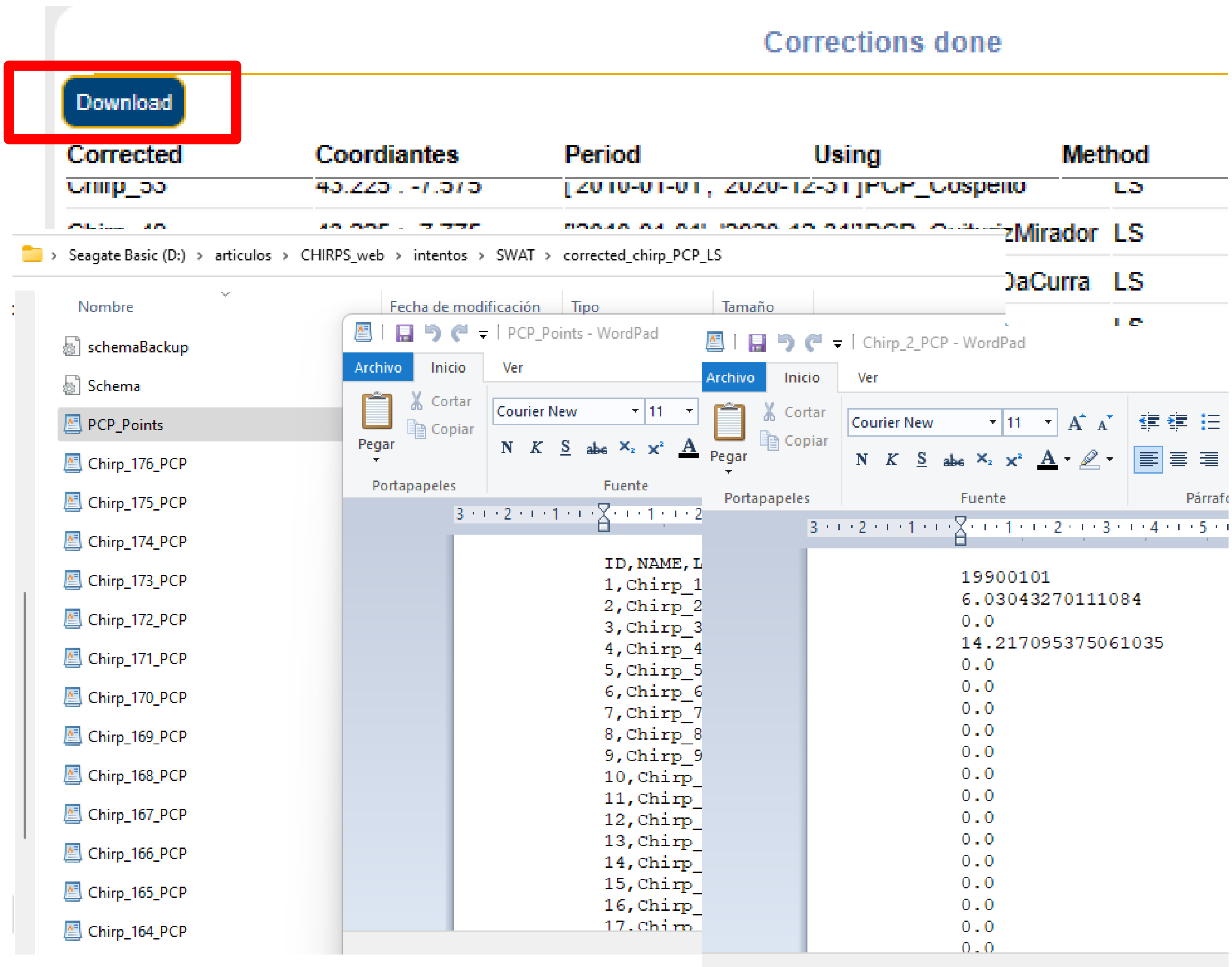
$$f(b_m) = \frac{\sigma(P_{obs,m})}{\mu(P_{LOCI,m}^{b_m})} - \frac{\sigma(P_{LOCI,m}^{b_m})}{\mu(P_{LOCI,m}^{b_m})}$$

Step 4: Download corrected data



- Bias-correction of nearest grid center to uploaded stations.
- Rest grid cells affected by interpolated coefficients using the inverse distance weighting method (IDW).

Step 4: Download corrected data



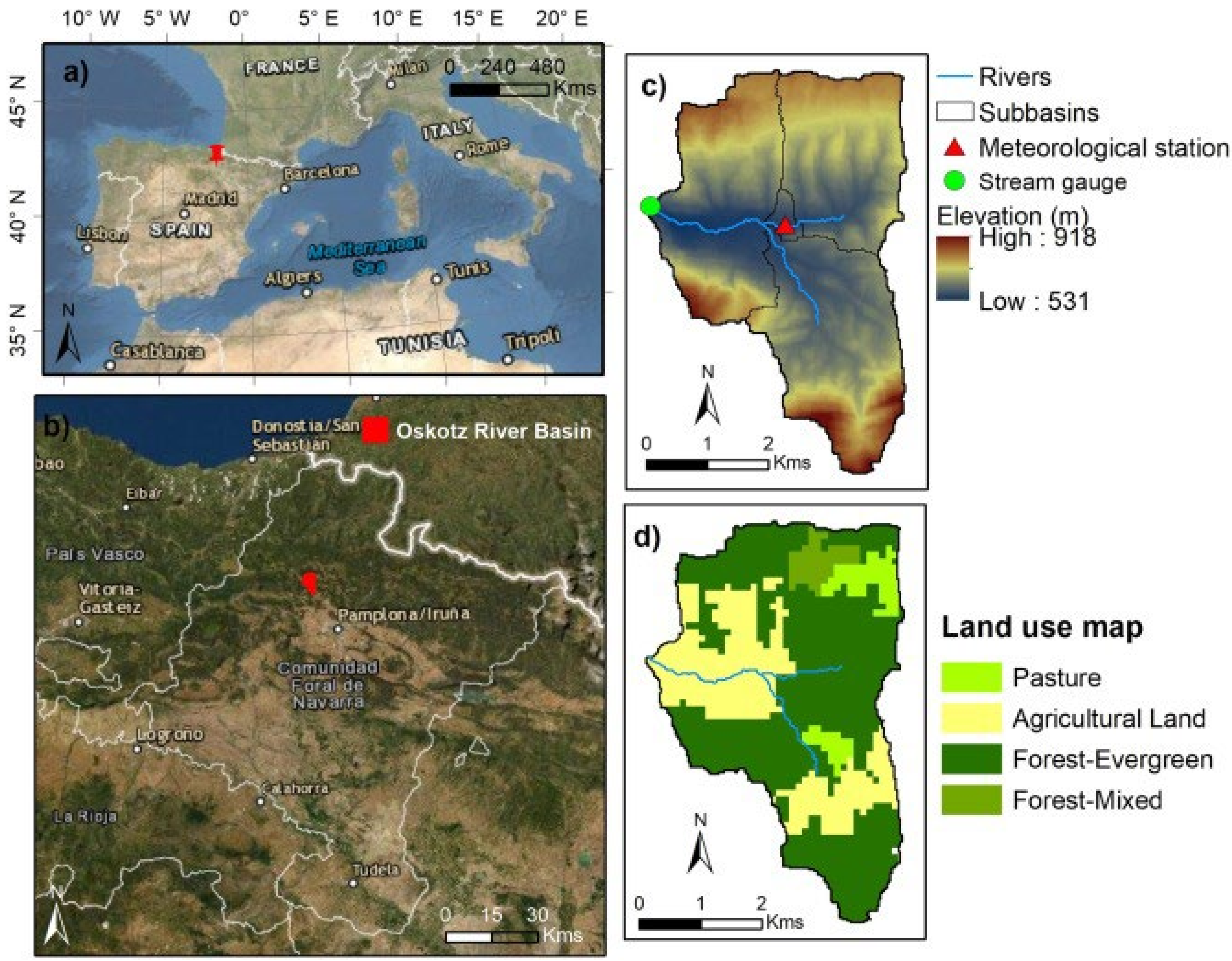
Introduction

Methodology

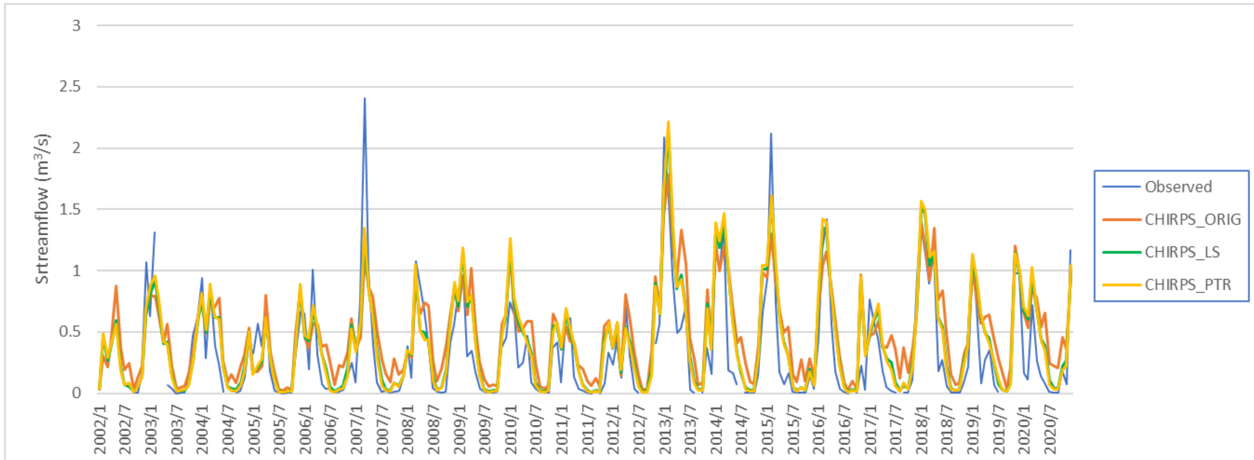
Study case

Conclusions

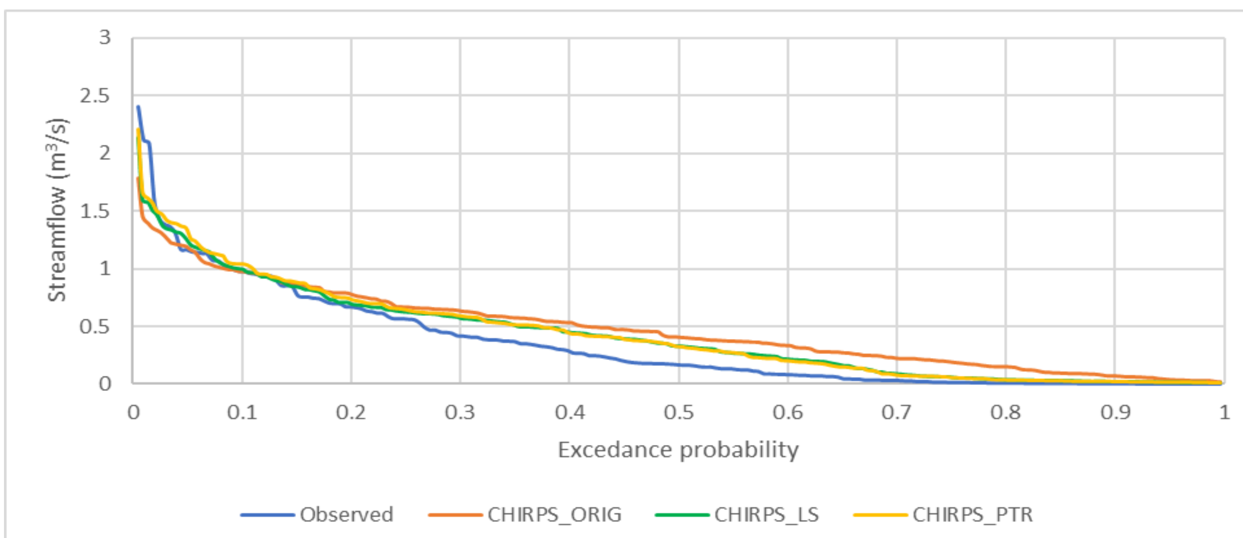
Study case



Hydrograph



Flow-Duration curve



Statistics

	CHIRPS_ORIG	CHIRPS_LS	CHIRPS_PT	CHIRPS_LOCI
R^2	0.65	0.76	0.77	0.46
NSE	0.54	0.70	0.70	0.52
PBIAS	-44.82%	-30.00%	-31.09%	46.72%

- **General underestimation for the highest flow peaks.**
- **Overestimation for medium/base streamflow for raw-CHIRPS**
- **Better performance for low flow with LS/PT.**
- **Significant improvement with LS and PT vs. raw-CHIRPS.**
- **Similar results with LS and PT.**
- **Increase R^2 and Nash-Sutcliffe efficiency by 17% and 30%.**
- **Decrease PBIAS around 15%.**
- **Poor performance with LOCI.**

Introduction

Methodology

Study case

Conclusions

- Application of the **bias-correction methods significantly improves** the flow simulation.
- CHIRPS Tool bias correction software enables **filling of missing precipitation records**.
- CHIRPS Tool provides a **dense grid data** of 0.05º resolution enhancing watershed spatial analysis.
- The CHIRPS tool is **quasi-global extension available** (50ºN-50ºS 180ºW-180ºE) hosted in http://facu.ucam.edu:8080
- CHIRPS Tool provides **a useful and easy-to-use** tool that will help research community and water managers to improve the feasibility of hydrological modelling.

Thank you for your attention!

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