

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

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CHIRP Tool bias correction

Load CHIRP region

Set region coordinates:
Latitude: 43.0 Longitude: -8.0
Latitude: 43.5 Longitude: -7.4
Set years to load:
From: 2000 To: 2020
Load region Reset

Chirp point loaded

Total points loaded: 143
Years: [2000, 2020]
Region:
latitude: [43.0, 43.5]
longitude: [-8.0, -7.4]
Correct Download CHIRP
Method: [LOCAL] Threshold: [1]

User stations uploaded

Total stations loaded: 6

Name	Lat	Lon	Years
PCP_CornoDeBoli	43.037	-7.893	[2005-06-09, 2020-10-26]
PCP_Sambreixo	43.146	-7.791	[2005-06-09, 2020-10-26]
PCP_Cospello	43.24	-7.555	[2019-10-04, 2020-10-26]
PCP_GulturizMirador	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]

Upload files

Corrections done

Download

Corrected	Coordianes	Period	Using	Method
Chirp_61	43.225 -7.575	[2000-01-01, 2020-12-31]	PCP_Cospello	LS
Chirp_57	43.225 -7.775	[2000-01-01, 2020-12-31]	PCP_GulturizMirador	LS
Chirp_81	43.325 -7.875	[2000-01-01, 2020-12-31]	PCP_MarcoDaCurra	LS
Chirp_99	43.375 -7.625	[2000-01-01, 2020-12-31]	PCP_Lanzos	LS
Chirp_1	43.025 -7.975	[2000-01-01, 2020-12-31]	ALL	IDW
Chirp_2	43.025 -7.925	[2000-01-01, 2020-12-31]	ALL	IDW

Web log

- 05/06/2023 - 12:20:39: Session user started.
- 05/06/2023 - 12:34:36: Chirp data extracted and loaded for user region
- 05/06/2023 - 12:36:38: User files uploaded.
- 05/06/2023 - 12:38:54: Chirp data corrected.

Outline

- ❑ Introduction: Scientifical Context and Objectives.

- ❑ Methodology
 - CHIRPS data-set
 - Rain gauge stations
 - Bias-correction techniques

- ❑ Study Case
 - Results
 - Discussion

- ❑ Conclusions.

Scientific Context

Introduction

Scientific context

Objectives

- **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.

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- 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)

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- 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.

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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.

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CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data)

- **35+ year** quasi-global (50°N-50°S) rainfall dataset of **0.05° 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/>



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

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- 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

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

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```
1 usage  gbequer@gmail.com <gbequer@gmail.com> *
def calculate_b_factor(self, serie):
    months = pd.DataFrame(
        {'count': self.observado_ajustado[self.parameter].groupby(self.observado_ajustado.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.observado_ajustado[
            (self.observado_ajustado.index.month == actual) | (self.observado_ajustado.index.month == pre) | (
                self.observado_ajustado.index.month == post)][self.parameter].mean()
        months.at[actual, "std_obs"] = self.observado_ajustado[
            (self.observado_ajustado.index.month == actual) | (self.observado_ajustado.index.month == pre) | (
                self.observado_ajustado.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)))
```

Step 1: Load CHIRPS region

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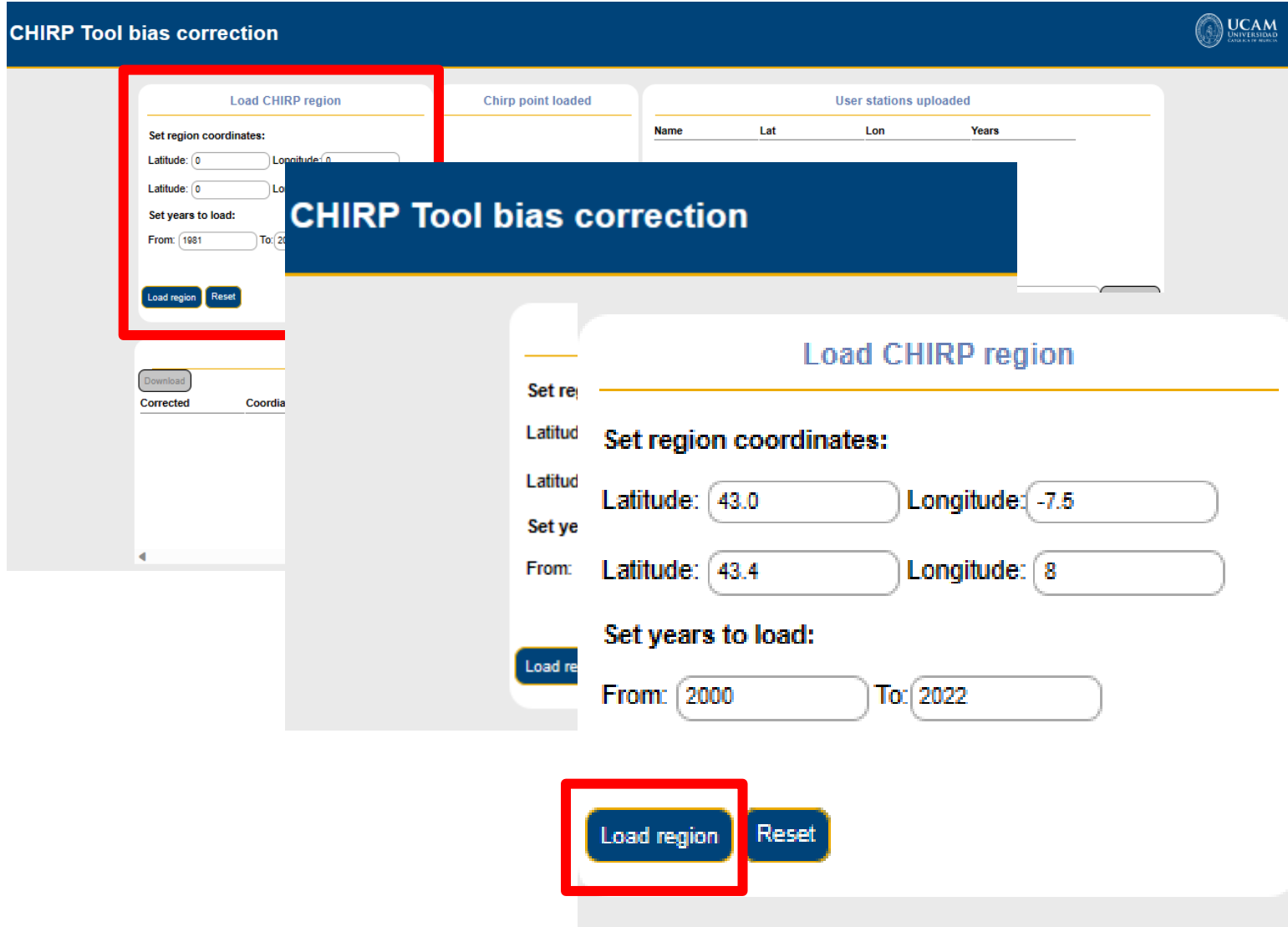
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The screenshot displays the 'CHIRP Tool bias correction' web interface. The main heading is 'CHIRP Tool bias correction'. The interface is divided into three sections: 'Load CHIRP region', 'Chirp point loaded', and 'User stations uploaded'. The 'Load CHIRP region' section is highlighted with a red box and contains the following fields:

- Set region coordinates:**
 - Latitude:
 - Longitude:
 - Latitude:
 - Longitude:
- Set years to load:**
 - From:
 - To:
- Buttons:** 'Load region' (highlighted with a red box) and 'Reset'.

The 'User stations uploaded' section contains a table with columns: Name, Lat, Lon, and Years.

A large blue overlay with the text 'CHIRP Tool bias correction' is present in the center of the interface.

A zoomed-in view of the 'Load CHIRP region' form is shown below the main screenshot, with the 'Load region' button highlighted by a red box. The input fields in this view are:

- Set region coordinates:**
 - Latitude:
 - Longitude:
 - Latitude:
 - Longitude:
- Set years to load:**
 - From:
 - To:
- Buttons:** 'Load region' (highlighted with a red box) and 'Reset'.

Step 1: Load CHIRPS region

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CHIRP Tool bias correction

Load CHIRPS region

Set region coordinates:
Latitude: 0 Longitude: 0
Latitude: 0 Longitude: 0

Set years to load:
From: 1981 To: 2022

Chirp point loaded

Name	Lat	Lon	Years
------	-----	-----	-------

User stations uploaded

Name	Lat	Lon	Years
------	-----	-----	-------

Chirp point loaded

Total points loaded: 99
Years: [2010, 2020]
Region:
latitude: [43.0, 43.4]
longitude: [-8.0, -7.5]

Download CHIRP

- PCP_Points
- Chirp_176_PCP
- Chirp_175_PCP
- Chirp_174_PCP
- Chirp_173_PCP
- Chirp_172_PCP
- Chirp_171_PCP
- Chirp_170_PCP
- Chirp_169_PCP
- Chirp_168_PCP
- Chirp_167_PCP
- Chirp_166_PCP
- Chirp_165_PCP
- Chirp_164_PCP

```
ID,NAME,LAT, LONG, ELEVATION
1,Chirp_1_PCP,43.025,-7.975, 0
2,Chirp_2_PCP,43.025,-7.925, 0
3,Chirp_3_PCP,43.025,-7.875, 0
4,Chirp_4_PCP,43.025,-7.825, 0
5,Chirp_5_PCP,43.025,-7.775, 0
6,Chirp_6_PCP,43.025,-7.725, 0
7,Chirp_7_PCP,43.025,-7.675, 0
8,Chirp_8_PCP,43.025,-7.625, 0
9,Chirp_9_PCP,43.025,-7.575, 0
10,Chirp_10_PCP,43.025,-7.525, 0
11,Chirp_11_PCP,43.025,-7.475, 0
12,Chirp_12_PCP,43.025,-7.425, 0
13,Chirp_13_PCP,43.025,-7.375, 0
14,Chirp_14_PCP,43.025,-7.325, 0
15,Chirp_15_PCP,43.025,-7.275, 0
16,Chirp_16_PCP,43.025,-7.225, 0
17,Chirp_17_PCP,43.075,-7.975, 0
```

Step 2: Upload rain gauge station data

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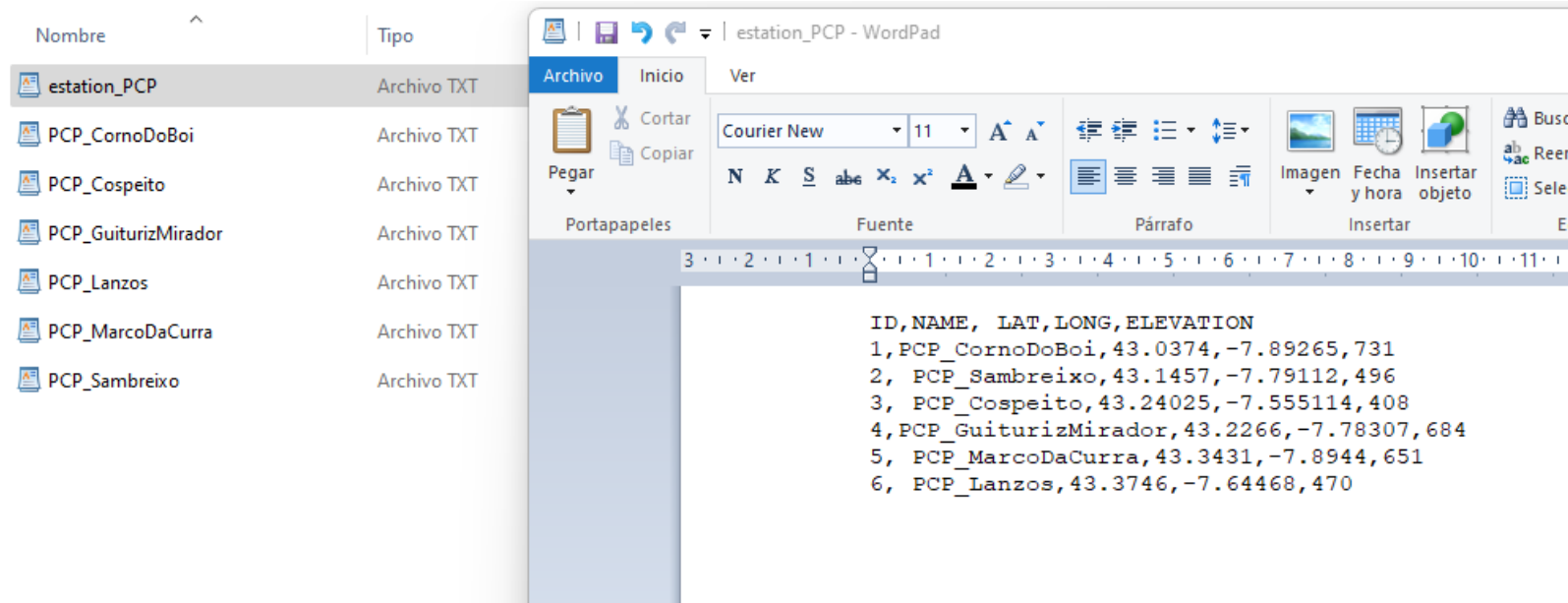
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The screenshot displays the 'CHIRP Tool bias correction' web interface. The 'User stations uploaded' section is highlighted with a red box. It features a table with columns for Name, Lat, Lon, and Years. Below the table is a file upload area with a button labeled 'Elegir archivo' (Choose file), a status message 'No se ha sele... ningún archivo' (No file selected... no file), and an 'Upload files' button. A 'Web log' window on the right shows a session start message: '05/06/2023 - 18:05:34: Session user started.' Below the main interface, a text box contains the instruction 'File compressed in ZIP' and another red box highlights the 'Elegir archivo' button.

Step 2: Upload rain gauge station data

- File compressed in ZIP



The screenshot shows a file explorer window on the left with a list of files:

Nombre	Tipo
estation_PCP	Archivo TXT
PCP_CornoDoBoi	Archivo TXT
PCP_Cospeito	Archivo TXT
PCP_GuiturizMirador	Archivo TXT
PCP_Lanzos	Archivo TXT
PCP_MarcoDaCurra	Archivo TXT
PCP_Sambreixo	Archivo TXT

Overlaid on the right is a WordPad window titled 'estation_PCP - WordPad'. The 'Archivo' menu is open, showing options like 'Cortar', 'Copiar', and 'Pegar'. The text area contains the following data:

```
ID,NAME, LAT, LONG, ELEVATION
1, PCP_CornoDoBoi, 43.0374, -7.89265, 731
2, PCP_Sambreixo, 43.1457, -7.79112, 496
3, PCP_Cospeito, 43.24025, -7.555114, 408
4, PCP_GuiturizMirador, 43.2266, -7.78307, 684
5, PCP_MarcoDaCurra, 43.3431, -7.8944, 651
6, PCP_Lanzos, 43.3746, -7.64468, 470
```

Elegir archivo PCP_Begonte.zip

Upload files

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User stations uploaded

Total stations loaded: 6

Name	Lat	Lon	Years
PCP_ComoDoBoi	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']

Elegir archivo

No se ha sele... ningún archivo

Upload files

Step 3: Bias correction

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Chirp point loaded

Total points loaded: 99

Years: ['2010', '2020']

Region:

latitude: [43.0, 43.4]

longitude: [-8.0, -7.5]

Download CHIRP

Correct

Method LOCI

Thresho
 Linear Scaling
 Power Transformation
 LOCI

- 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):

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

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

- Power transformation (PT):

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

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

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

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Load CHIRP region

Set region coordinates:

Latitude: Longitude:

Latitude: Longitude:

Set years to load:

From: To:

Chirp point loaded

Total points loaded: 99

Years: ['2010', '2020']

Region:

latitude: [43.0, 43.4]

longitude: [-8.0, -7.5]

User stations uploaded

Total stations loaded: 6

Name	Lat	Lon	Years
PCP_ComoDoBoi	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']

Corrections done

Corrected	Coordiantes	Period	Using	Method
Chirp_55	43.225 : -7.575	['2010-01-01', '2020-12-31']	PCP_Cospeito	LS
Chirp_49	43.225 : -7.775	['2010-01-01', '2020-12-31']	PCP_GuiturizMirador	LS
Chirp_69	43.325 : -7.875	['2010-01-01', '2020-12-31']	PCP_MarcoDaCurra	LS
Chirp_85	43.375 : -7.625	['2010-01-01', '2020-12-31']	PCP_Lanzos	LS
Chirp_1	43.025 : -7.975	['2010-01-01', '2020-12-31']	ALL	IDW
Chirp_2	43.025 : -7.925	['2010-01-01', '2020-12-31']	ALL	IDW
Chirp_4	43.025 : -7.825	['2010-01-01', '2020-12-31']	ALL	IDW

- 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

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Download

Corrected	Coordiantes	Period	Using	Method
Chirp_33	43.225 - -7.373	[2010-01-01, 2020-12-31]	PCP_Cospello	LS
Chirp_40	43.225 - -7.373	[2010-01-01, 2020-12-31]	PCP_Cospello	Mirador LS
Chirp_46	43.225 - -7.373	[2010-01-01, 2020-12-31]	PCP_Cospello	JaCurra LS

Seagate Basic (D:) > articulos > CHIRPS_web > intentos > SWAT > corrected_chirp_PCP_LS

ID	NAME	Value
1	Chirp_1	19900101
2	Chirp_2	6.03043270111084
3	Chirp_3	0.0
4	Chirp_4	14.217095375061035
5	Chirp_5	0.0
6	Chirp_6	0.0
7	Chirp_7	0.0
8	Chirp_8	0.0
9	Chirp_9	0.0
10	Chirp_10	0.0
11	Chirp_11	0.0
12	Chirp_12	0.0
13	Chirp_13	0.0
14	Chirp_14	0.0
15	Chirp_15	0.0
16	Chirp_16	0.0
17	Chirp_17	0.0

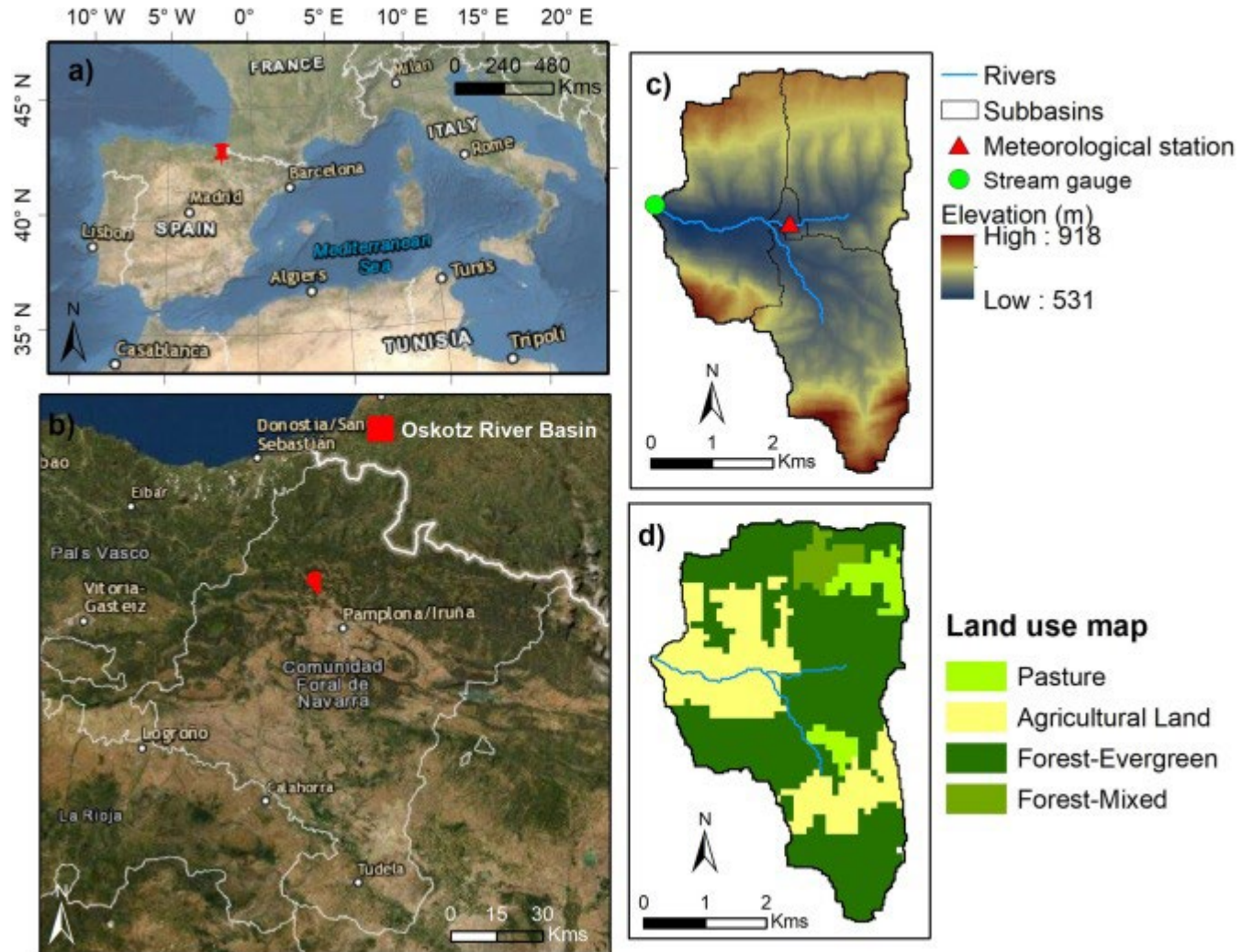
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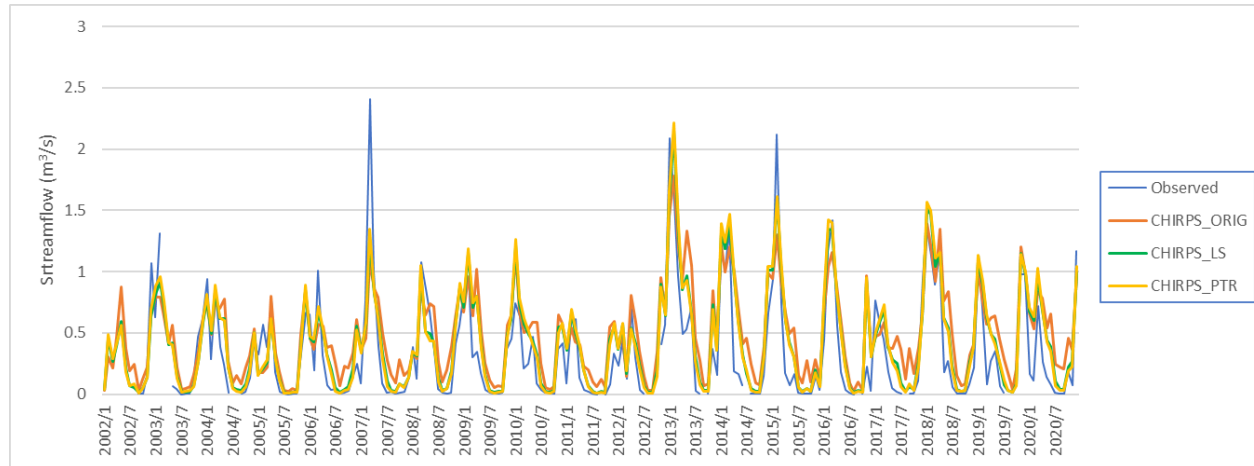
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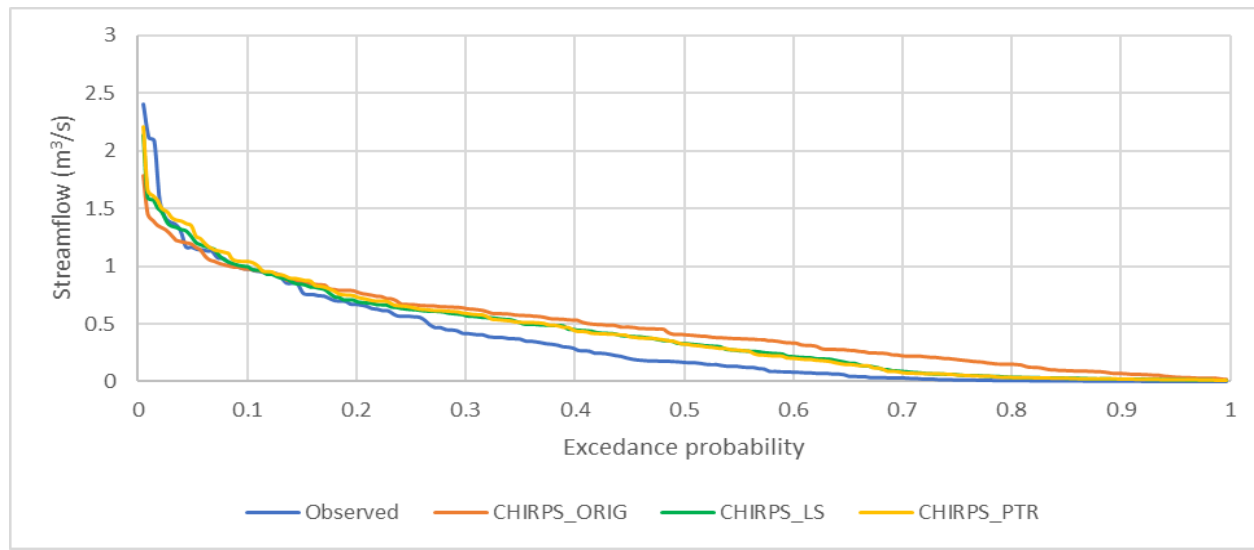
Hydrograph

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Flow-Duration curve



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	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 R² and Nash-Sutcliffe efficiency by 17% and 30%.
- Decrease PBIAS around 15%.
- Poor performance with LOCI.

Introduction

- Application of the **bias-correction methods significantly improves** the flow simulation.

Methodology

- CHIRPS Tool bias correction software enables **filling of missing precipitation records**.
- CHIRPS Tool provides a **dense grid data** of 0.05° resolution enhancing watershed spatial analysis.
- The CHIRPS tool is **quasi-global extension available** (50°N-50°S 180°W-180°E) hosted in <http://facu.ucam.edu:8080>

Study case

- 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.

Conclusions



Thank you for your attention!



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