Rainfall prediction in the Mondego river basin using CV and DL

Faculdade de Engenharia da Universidade do Porto

Master in Data Science and Engineering

Computer Vision

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Objectives | Methodology

Objective

Using weather forecasts/reanalysis datasets, **estimate the rainfall depth in a river basin**.

Methodology

Target: **daily rainfall** for the **Mondego river basin** (Thiessen method).

Dataset available here: https://filesender.fccn.pt/?s=download&token=0fe569f1-69ea-4b7a-bfb1-f68cb004c953

Workplan

1. Compute daily rainfall in the Mondego river basin (target)	ipynb
1.1. Create Thiessen construction for Portuguese basins	[1]
1.2. Identify which Thiessen polygons intersect Mondego river basin	[1]
1.3. Download data from SNIRH for period 1950 – 2021	[1]
1.4. Load data to dataframes.	[2]
1.5. Verify missing values	[2]
1.6. Eliminate weather stations with too many missing values	[2]
1.7. Reconstruct Thiessen polygons with validated weather stations	[2]
1.8. Compute the spatial average of the rainfall in the Mondego RB	[2]

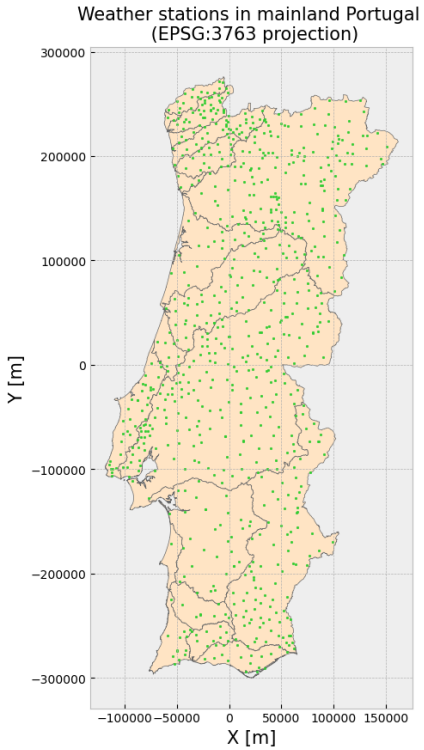
2. Create ECMWF meteorological dataset (tp, tcc, t2m)	ipynb
2.1. Define coordinates (lat/long) for download	[3]
2.2. Download data from ECMWF for period defined in 1.7	[4]
2.3. Convert lat/long to Carthesian coordinates (EPSG:3763)	[3]
2.4. Generate images (rainfall, temperature, total cloud coverage)	[5]

3. Develop CNN for spatial averaged rainfall prediction (VC | TAAC Q2)	ipynb
3.1. Dataset preprocessing	[6]
3.2. Data loader	[7]
3.3. CNN model	[7]
3.4. Training routine	[7]
3.5. Evaluation routine	[7]
3.6. Hyper parameter tunning	[7]
3.7. Testing different image sizes	[7]
3.8. Results evaluation	[7]

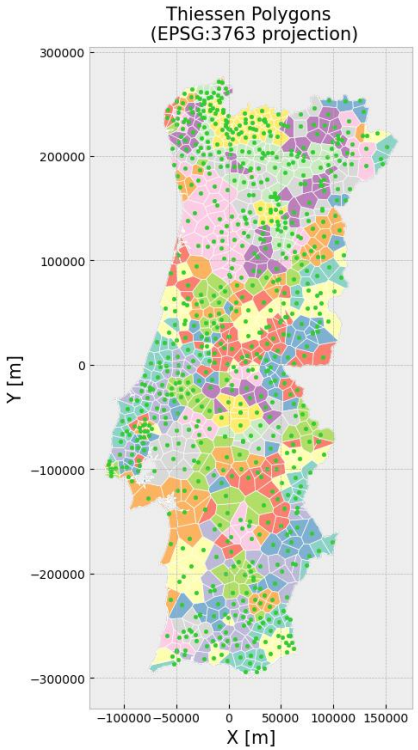
Notebooks	Machine
[1] 20221025_VC_SNIRH_Download	Local
[2] 20221101_VC_SNIRH_Preprocessing	Local
[3] 20221025_VC_ECMWF_Grid_Basin	Local
[4] 20221030_VC-ECMWF_Download	Local
[5] 20221101_VC-ECMWF_ExportImages	Local
[6] 20221110_VC_CNN_dataset	Colab
[7] 20221114_VC_CNN	Colab

Dataset available here: https://filesender.fccn.pt/?s=download&token=a0d86e5b-f854-4133-93a5-1cc924e5f4a1

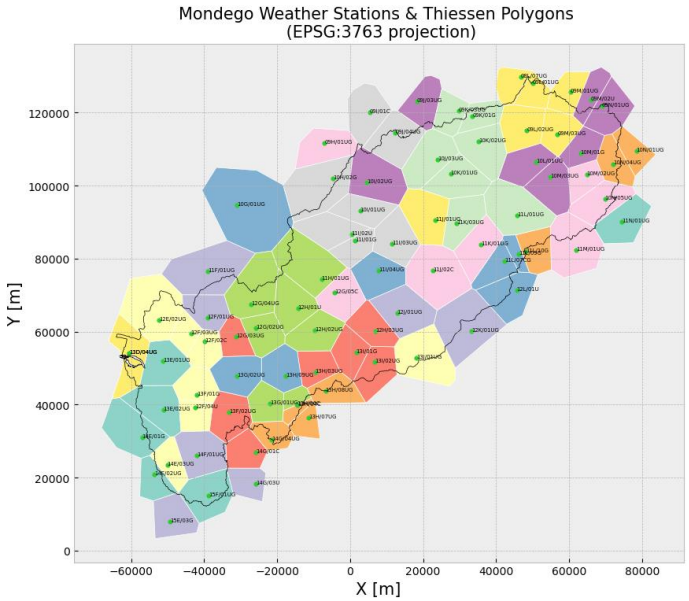
1. Daily rainfall in the Mondego river basin



Voronoi tesselation



Mondego river basin

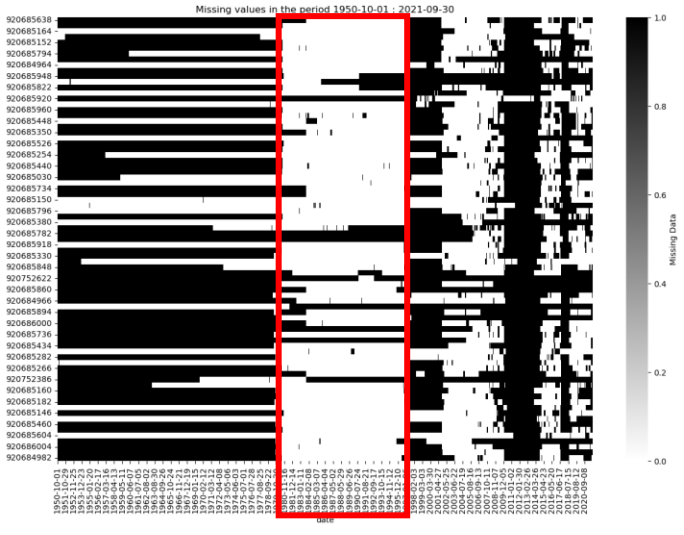



```
# Data sources
# basins boundaries
https://sniambgeoviewer.apambiente.pt/GeoDocs/shpzips/AtAgua_Bacias_bacias_snirh_PC.zip
# weather stations network
https://sniambgeoviewer.apambiente.pt/GeoDocs/shpzips/AtAgua_Meteo_METEO_NET_PC.zip
```

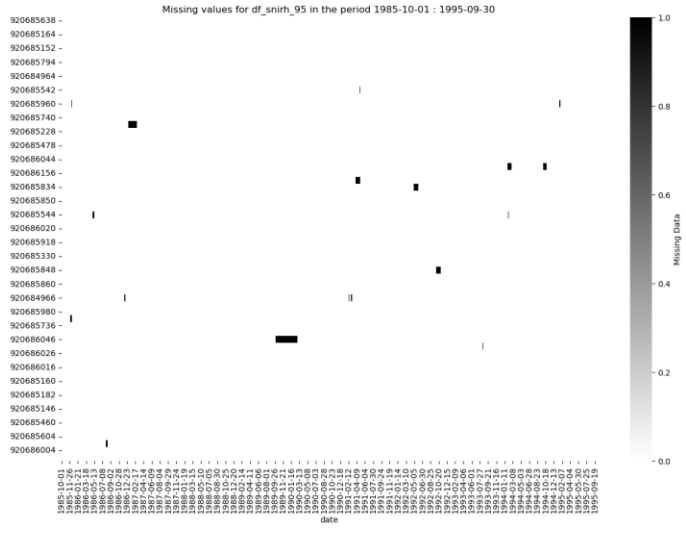
Notebooks:
[1] 20221025_VC_SNIRH_Download

Results:
83 weather stations whose Thiessen polygon intercepts the Mondego river basin

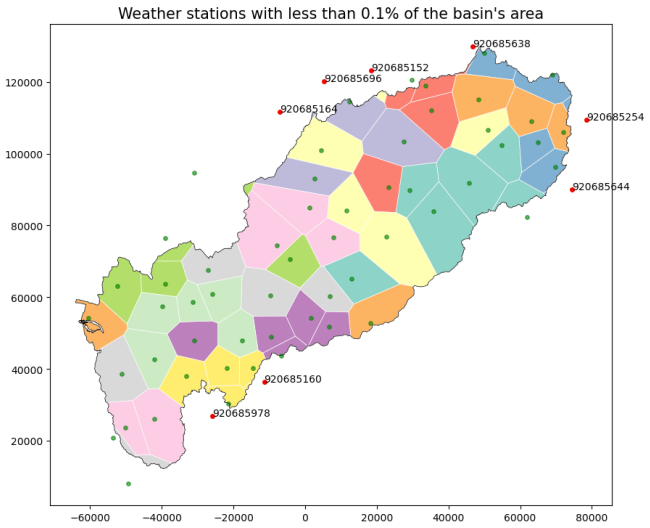
1. Daily rainfall in the Mondego river basin



MV 1950-2021



MV 1985/10-1995/09



Stations with 95% complete records

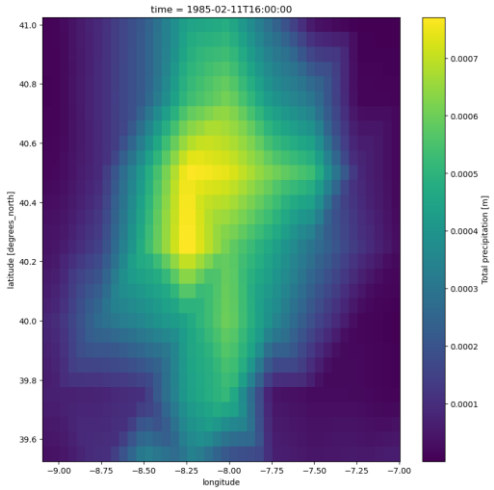
The **spatial average** of days with MV was computed **eliminating the stations with MV** and **recomputing the Thiessen polygons.**

Results:
Period with most complete records: 1985 - 1995
64 weather stations with records >95% of the time
48 weather stations with complete dataset.
Rainfall spatial average over the river basin (target)

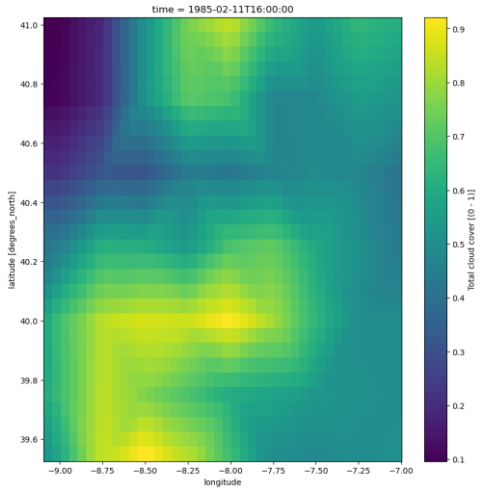
Data sources
Daily rainfall
www.snirh.pt

Notebooks:
[2] 20221101_VC_SNIRH_Preprocessing

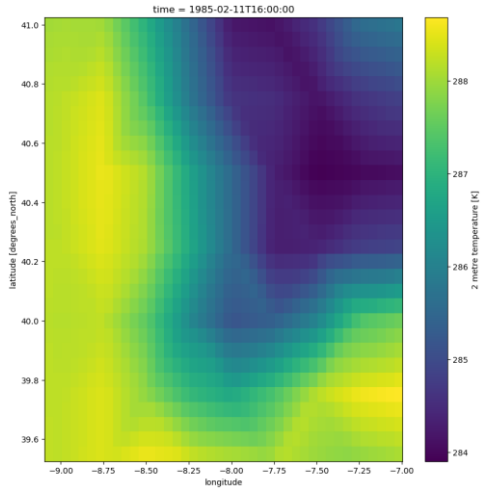
2. ECMWF meteorological dataset (tp, tcc, t2m)



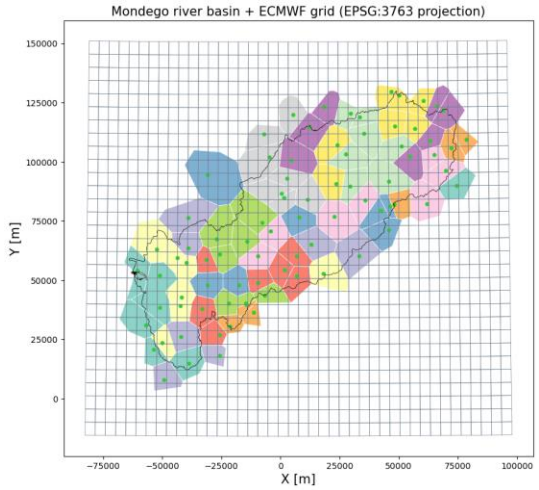
Total precipitation (tp)



Total cloud coverage (tcc)



2m temperature (t2m)



Raster grid (30 x 42)

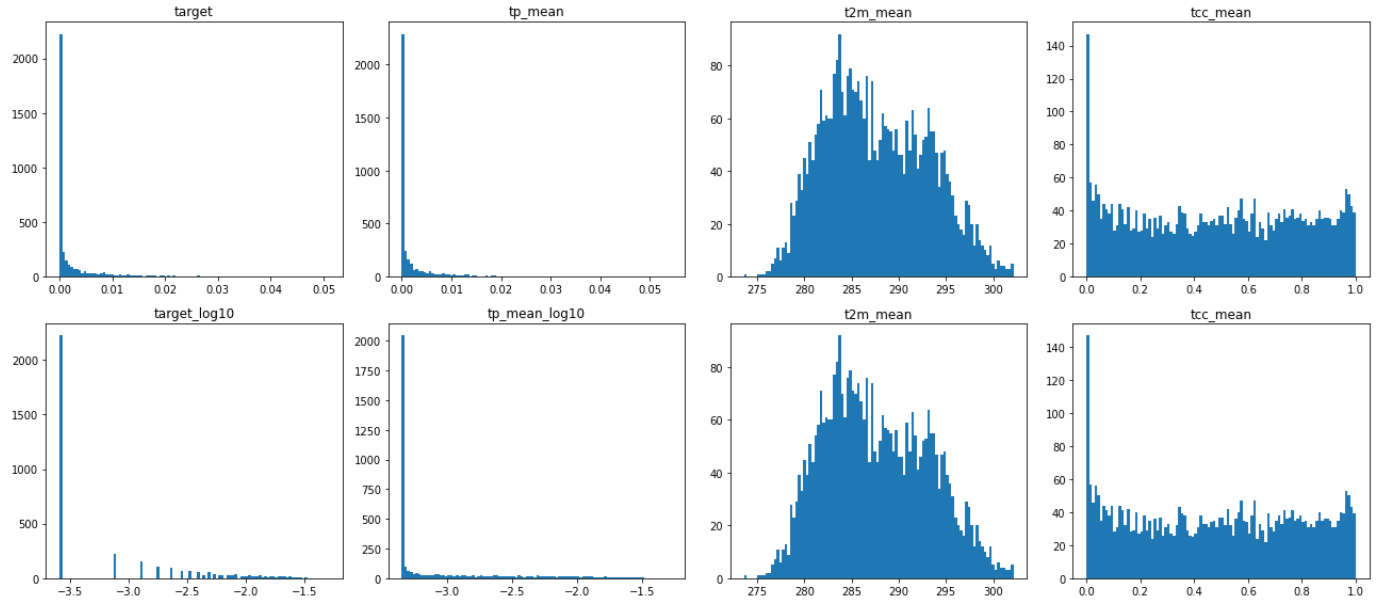
```
# Data sources
# hourly values of total precipitation,
total cloud coverage, 2m temperature
https://cds.climate.copernicus.eu/cdsapp#!
/dataset/reanalysis-era5-land?tab=overview
```

Notebooks:
[3] 20221025_VC_ECMWF_Grid_Basin
[4] 20221030_VC-ECMWF_Download
[5] 20221101_VC-ECMWF_ExportImages
[6] 20221110_VC_CNN_dataset

Results:
ECMWF data on tp, tcc and t2m (features)
1 raster per hour (0h-1h, 1h-2h, …)
Range of lat/long covering the basin

3. CNN dataset

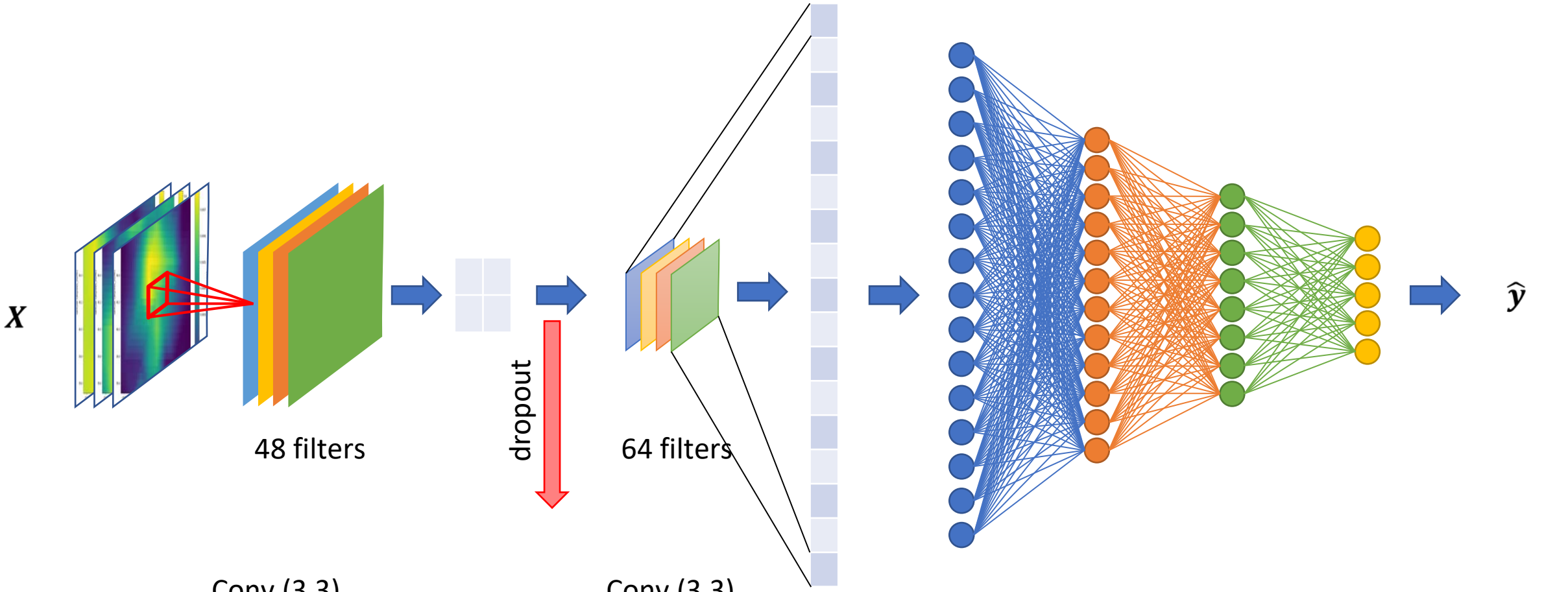
- Composite images
  (tp, tcc, t2m)
- 3652 instances



- Highly imbalanced
- Penalize frequent values
- Log transformation did not produce significant improvements
- MinMax normalization

Notebooks:
[7] 20221114_VC_CNN

3. CNN architecture



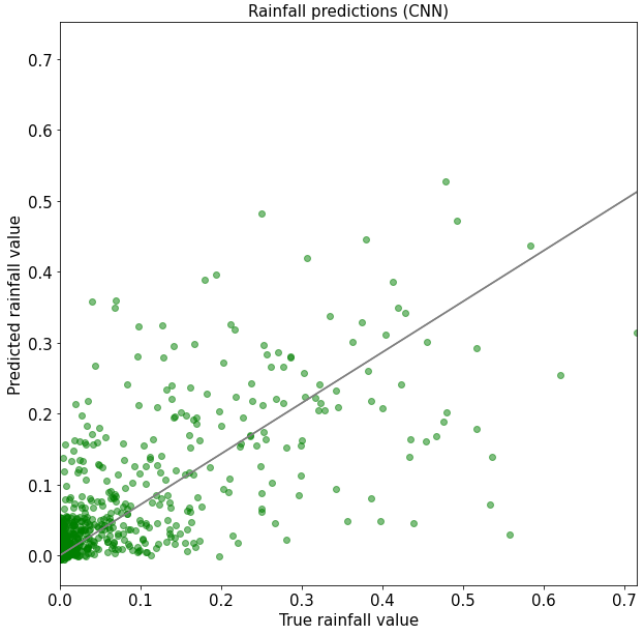
Notebooks:
[7] 20221114_VC_CNN

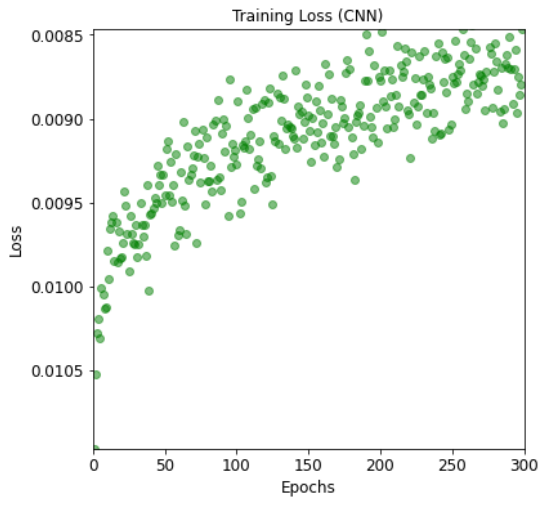
3. CNN results

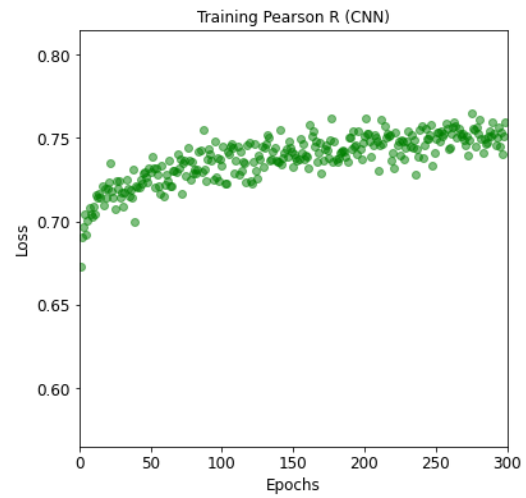
- Best model:
  - Optimizer : Rprop
    - Adam, SGD, NAdam, RMSProp
  - Parameters:
    - batch size - 64
    - epochs – 300
    - lr – 0.001
  - Loss (weighted MSE): 0.007
  - Small values weight: 100
  - Pearson R: 74.7%

Note: Different runs with same parameters produce similar but different results

Notebooks:
[7] 20221114_VC_CNN







Highlights

- Original research
- Dataset created from scratch
- Custom dataloader and loss function (weighted MSE)
- Dataset imbalance compensation (log transform and penalties)
- Successfully trained and tested a CNN for regression problem
- Hyperparameter tunning and different optimizers tested
- Too little sleep!

Future work

- Different CNN architectures
- Effect of image overlap with river basin limits
- Images with time information (e.g., composite tp images [d-3:d+3], hourly images)
- Data augmentation for least represented values of the target
- Other type of features (e.g., cumulative values, humidity, atmospheric pressure, etc.)
- Other datasets (e.g. ERA5-Land hourly data, PERSIANN)
- Write an article!

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