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Study Of The Impact Of Climate Change On Precipitation In Paris Area Using Method Based on Iterative Multiscale Dynamic Time Warping (IMs-DTW)

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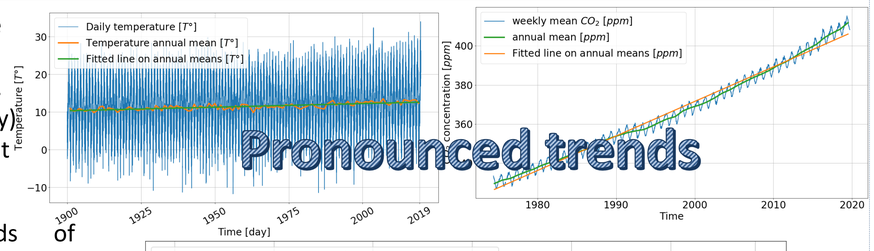
0.ABSTRACT

Change on precipitation is constrained by finding a way to evaluate the evolution of precipitation variability over time. Classical approaches (feature-based) have shown their limitations for this issue due to the intermittent and irregular nature of precipitation. In this study, we present a novel variant of the Dynamic time warping method quantifying the dissimilarity between two rainfall time series based on shapes comparisons, for clustering annual time series recorded at daily scale. This shape-based approach considers the whole information (variability, trends and intermittency…). We further labeled each cluster using a feature-based approach. While testing the proposed approach on the time series of Paris-Montsouris, we found that the precipitation variability increased over the years in Paris area.

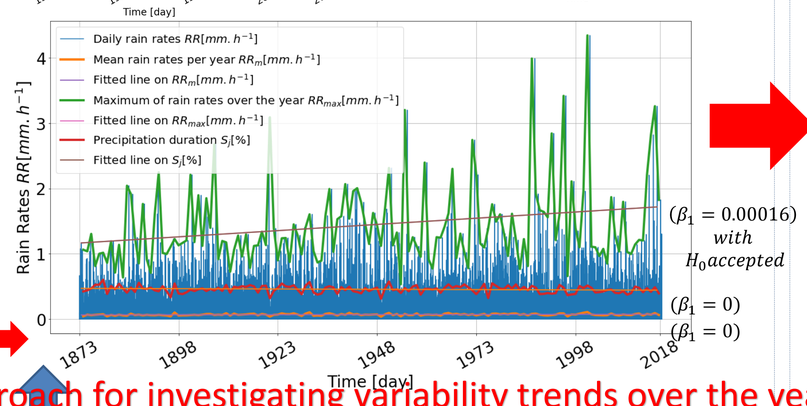
I. MOTIVATION

Unlike temperature and CO_2, evolution of precipitation (ex. trend and variability) seems to be difficult to investigate.



Analyzing trends of features / characteristics of precipitations (such as Mean rain rates RR_m, Maximum rain rates RR_{max} or precipitation duration per year S_j) over the years **is not conclusive.**

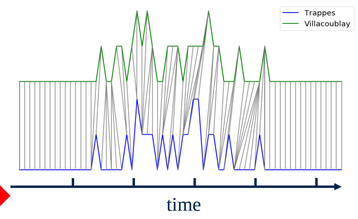
In front, a linear model is fitted for some characteristics.



Need adapted approach for investigating variability trends over the years

Iterative Multiscale Dynamic Time Warping(IMs-DTW)

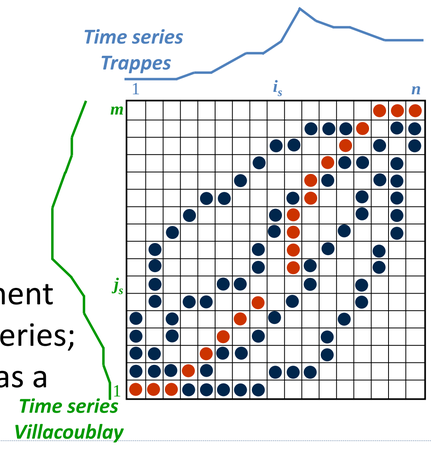
Instead of comparing extracted features seeking for trends, an idea is perform a global comparison using IMS-DTW like below :



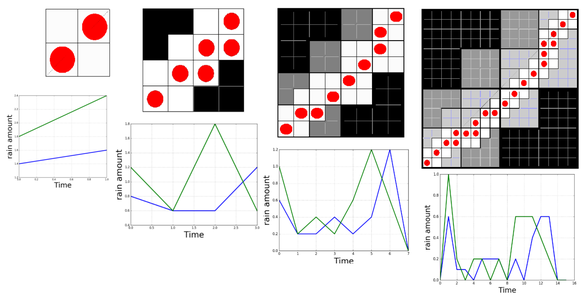
$$d^2(x,y) = \sum_{i=1, j=P(i)}^{n} (x_i - y_j)^2$$

With :

- $P = \{P(i)\}$ the alignment linking the two time series;
- It is usually searched as a path in the graph →



In addition of classic constraints used for searching the path (see Sakoe & Chiba 1970), our version "IMS-DTW" is constrained by multiscale similarity to search for the path



II. METHOD

START

split the long daily time series into a set of N annual time series

- Compare all pairs (i,j) of the NxN annual time series using IMs-DTW,
- and Compute the dissimilarity scores

Perform K-medoids clustering on annual time series based on dissimilarity scores

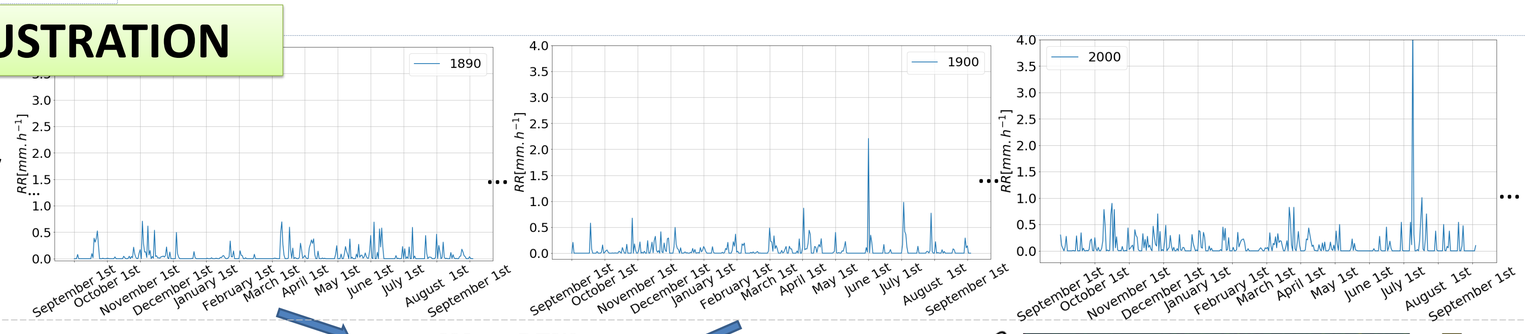
Label clusters based on a deep analysis of its medoids and the characteristics it shares with the cluster.

Analyze the evolution of clusters frequencies over time.

END

III. EVALUATION AND ILLUSTRATION

- This long time series is measured between Sept.1st, 1873 and Aug. 31st, 2019 at the daily scale in Paris-Montsouris Stations.
- It was split into 146 annual time series (from september 1st to August 31st)



$IMs - DTW$

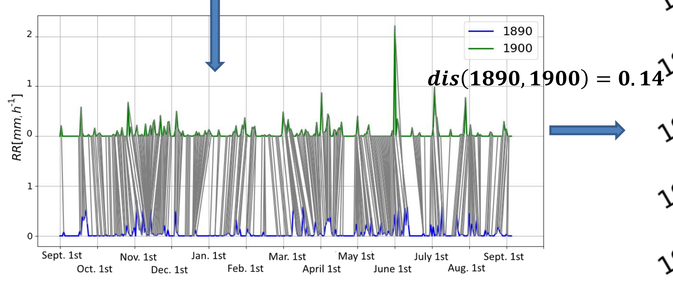


Fig. 1 illustrates, by way of example, the alignment obtained between the two annual time series representing years 1890 and 1900.

- The alignment structure ensures the association of the peaks and the rainy periods of the two years.
- The associations of the matching present relatively small offsets with up to two weeks.
- This observation is true for all the alignments proposed by the IMS-DTW between the 146 times series.

Fig. 1 **The alignment linking the rainfall time series 1890 to 1900**

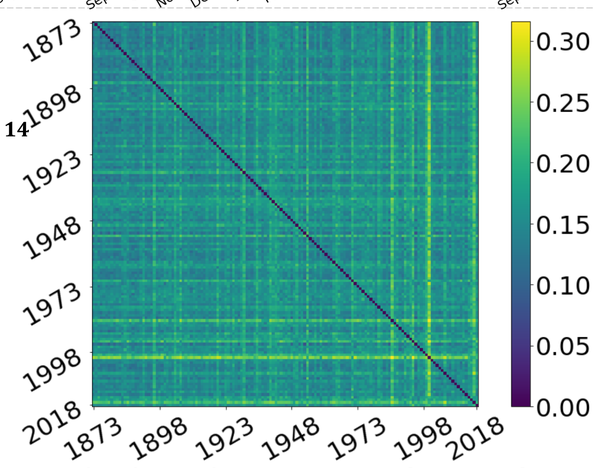
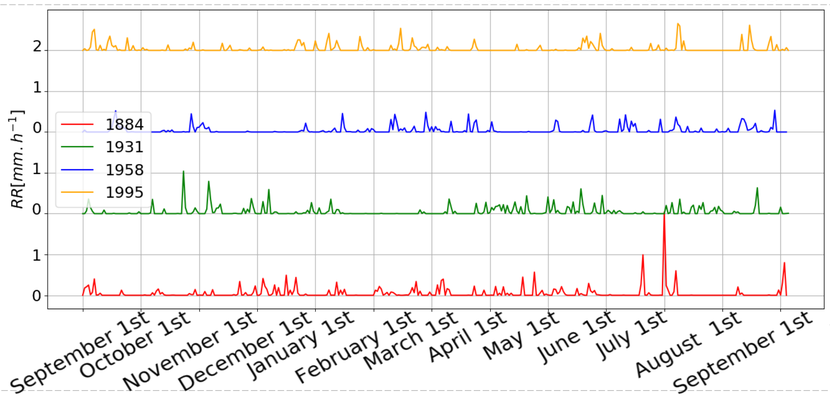


Fig. **the dissimilarity matrix D (146x146) between the 146 annual time series measured in Paris-Montsouris between 1873 and 2019**

" k-medoids is a classical partitioning technique of clustering, which clusters the data set of n objects into k clusters, with the number k of clusters assumed known a priori and chooses the closest object to the center as medoid for each cluster ". (example →

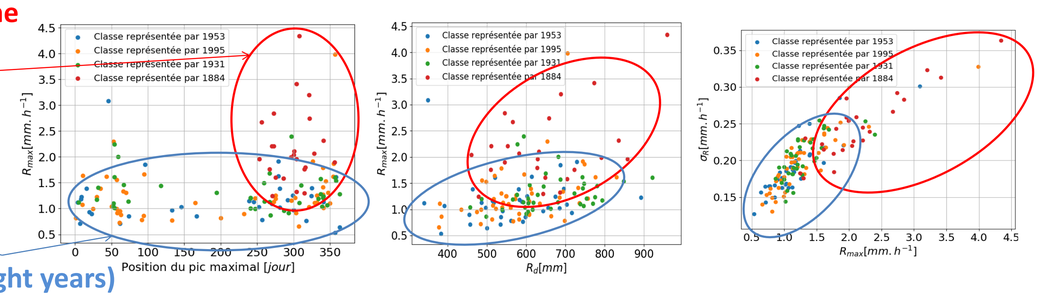
In front, k-medoids with (k=4) using the dissimilarity scores in *D* (fig. 2) chooses the 4 annual time series as centers (medoids).



medoids	RR_{max} $[mm.h^{-1}]$	σ_R $[mm.h^{-1}]$	H_d $[mm]$	S_R $[jour]$	$pic\ max$	Nb Events
1884	2.04	0.22	459.90	142	June 28th	56
1931	1.04	0.16	457.40	149	Oct. 23rd	60
1953	0.53	0.13	382.90	146	Aug. 24th	53
1995	0.66	0.14	378.10	134	July 4th	62

C4 (remarkable years with extreme variability)

C1 (drought years)



- Considering the appearance frequency of each cluster in seven successive 26 years' time intervals between 1873 and 2019 allows studying the possible evolution of precipitation.

Table 2. shows The temporal evolution of frequencies for each cluster [% by column]. →

Temporal window		Cluster C1	C2	C3	C4
1873	1899	29	19	16	07
1892	1918	21	19	19	14
1911	1937	18	15	29	11
1930	1956	18	11	24	25
1949	1975	21	23	81	21
1968	1994	18	23	11	21
1987	2018	09	28	16	36
Gradient		↘	↘↗	↗↘	↗

⇨With a coarse time window:

- the presence of the first cluster C1 (drought years) decreases over time;
- while that of C4 (remarkable years with extreme variability) increases or stagnates at the same time

which corroborates the assumption that the precipitation variability increases over time (# warmer climate) between 1873 and 2019.

IV. CURRENT WORK

The proposed method shows that :

- there exists a temporal evolution of precipitation when studiying Paris-Montsouris time series.

Limitations of the current work include :

- the fact that we have not yet demonstrated the robustness of the results in table 1, i.e. test if other rainfall time series measured in Paris area could lead to similar results.

Future work :

- Investigate if results show a real impact of climate change rather than just representing a temporal correlation.
- exploring the correlation between the defined clusters and environmental parameters (such as temperature).
- We also plan to extend the study area and to use other rainfall time series.

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