Rainfall trend in Lyon in the context of climate change: an increase in rainfall at risk according to two weather type classifications

Evolution des précipitations à Lyon dans le contexte du changement climatique : une augmentation des pluies à risque selon deux types de classifications synoptiques

F. Renard, L. Alonso

University Jean Moulin Lyon 3, UMR 5600 CNRS Environment City Society, France - florent.renard@univ-lyon3.fr

RÉSUMÉ

Le changement climatique actuel est un enjeu d'ampleur mondial qui a des conséquences sur la nature et la fréquence des précipitations locales. Ces modifications pluviométriques associées à une intensification du développement urbain impactent la gestion des eaux pluviales. Cette étude se propose d'étudier les évolutions pluviométriques des pluies à risque à l'aide des configurations synoptiques associées. Pour cela, deux catalogues du *Deutscher WetterDienst* sont utilisés : la classification subjective *Grosswetterlagen* et l'*Objective Weather Type Classification*. Les évolutions et tendances des circulations à l'origine de précipitations sont étudiées à l'échelle annuelle et à l'échelle saisonnière pour les précipitations abondantes, longues et intenses à l'aide de tests de Mann-Kendall et de la pente de Sen, de Pettitt, du SNHT, de Van Neuman et de Buishand. Les résultats indiquent un net accroissement des circulations pluviogènes du Sud et du Sud-Ouest et de leurs déclinaisons. Ces évolutions sont à prendre en considération pour la gestion des eaux en milieu urbain car ces circulations sont précisément à l'origine des pluies les plus hautes et les plus intenses. En conséquence, un ajustement des stratégies et des solutions associé à une évolution des pratiques s'avèrent nécessaire afin de s'adapter au mieux à ces évolutions pluviométriques.

ABSTRACT

Current climate change is a global issue that impacts the nature and frequency of local rainfall. These rainfall changes associated with an intensification of urban development have an impact on stormwater management. This study proposes to analyse the rainfall evolutions of heavy and intense rain using the associated synoptic configurations. For this, two catalogues of the *Deutscher WetterDienst* are used: the *Grosswetterlagen* subjective classification and the *Objective Weather Type Classification*. The evolutions and trends of the precipitation circulations are studied on an annual and seasonal scale for abundant, long and intense precipitation using Mann-Kendall and Sen slope tests, Pettitt, SNHT, von Neuman and Buishand tests. The results indicate a marked increase in rainfall Southerly and South-westerly circulations and their variations. These evolutions are to be taken into account for urban water management because these circulations are precisely at the origin of the highest and most intense rains. Consequently, an adjustment of the strategies and solutions associated with an evolution of the practices is necessary in order adapt to these climate evolutions.

KEYWORDS

Evolution, Intense rainfall, Objective Weather Type Classification, Southerly circulations, Grosswetterlagen

1. FRAMEWORK

Sanitation systems are now considered as key elements in the development of urban systems, especially for their benefits in terms of health and safety of property and people. The first systems

created consist of piped systems built to evacuate rain and waste water as quickly as possible out of the cities. Their very strong growth has considerably increased the drained surfaces, which has inevitably led to an increase in the volumes and flows in transit in the networks. Very quickly, and despite the arrival of separation networks, they have been saturated during heavy rains, generating risks of flooding by runoff. This phenomenon is concerning seen as more than half of the world's population currently lives in urbanized areas, according to the Population Reference Bureau[1], and thus a large portion of the population is exposed to it. The problem will only worsen, seen as by 2050, 70% of the population will live in urban areas, and no trend reversal is apparent (State of World Population, 2007). The study area of the Métropole de Lyon (1.3 million inhabitants, located in the south-eastern quarter of France) is particularly affected with several dozen claims each year, which are the subject of compensation, following intense thunderstorms (e.g. 7 June 2015: 32.4 mm in 30 minutes) or longer rain events (e.g. 7 September 2010: 104.1 mm). As a result, management has undergone a notorious evolution, often compared to a paradigm shift, and Lyon is a representative French example. Thus, new management methods are based on principles that mimic natural water cycles and are sometimes referred to as biomimetics. These alternative techniques have the main objectives of managing the precipitation in situ and slowing the flow.

These new management methods, however, come in a context of climate change. Subject to numerous studies on a global scale, future climate changes are, on the other hand, much less well documented at the local level. The different model outputs whose resolution does not allow a precise characterization of the local evolution of the precipitations are still difficult to interpret for the managers. As a result, a weather type classification system approach was initiated in Lyon (Renard et al., 2015), based on the rainy days and the characteristics of the episodes, since "a long catalogue of past weather regime events can give evidence for climate trends and their impacts, both in historical and recent times" (James, 2007). However, this study was based on the Grosswetterlagen Hess-Brezowsky classification (Gerstengarbe and Werner., 1999). This classification is subjective which means that several specialists can give different results for the same day of study, even if this probability remains low. Therefore, it is proposed here to use the Objective Weather Type Classification (OWTC – Bissolli and Dittmann, 2001). Contrary to the Grosswetterlagen and according to the German Meteorological Service (Deutscher Wetterdienst DWD) that produces both classifications that are consecutively continued, this objective classification is unambiguously defined and numerically reproducible with the same results. The Grosswetterlagen covers a large area of Central Europe and the OWTC covers mainly Germany with Lyon in the study area. As a consequence, this new study has four objectives: to update the previous study using the Grosswetterlagen to see if the trends of situations favourable to intense precipitation continue, apply the same method using the objective catalogue, study the evolution at annual level but also with a seasonal focus and compare the results obtained using both classifications. The expected results should make it possible to provide support for the establishment of a sustainable flood risk management policy for urban stormwater, particularly for the design of structures. The catalogues used in this study are only valid for the areas for which they have been created, but similar approaches can be used on other continents, with appropriate weather regimes.

2 METHODOLOGY

The aim of this study is to analyse the synoptic configurations of different types of precipitations and investigate their evolution in the context of climate change, in order to adjust the strategies and solutions for integrated and sustainable water management in Lyon. However, this methodology can be applied nearly anywhere in Europe with the same catalogues. Here, three kinds of precipitations are studied: the heaviest in terms of accumulated water height, the longest and the most intense. To get a representative panel for each ones, the weather types of the 100 longest, most abundant and most intense episodes are analyzed using the Grosswetterlagen and OWTC catalogues since 1881 and since 1980 to 2017, respectively, on an annual and a seasonal basis. Trends are analysed using the Mann-Kendall test and the Sen's slope. The absence of autocorrelation is verified beforehand. Breaks are analysed using the Pettitt, SNHT (standard normal homogeneity test), Buishand and von Neumann tests. Trends in annual and seasonal rainfall totals and number of rainy days are also analysed. Lyons rains (Lyon - Bron raingauge) are provided by the French Meteorological Service (Météo-France). Since this methodology is only based on descriptive statistics solely concerned with properties of the observed data not sampled from a larger population, there is no problem with statistical inference and multiple testing problems.

[1] https://www.prb.org/

3 RESULTS

No trend can be detected on the annual sum of rainy days but the annual rainfall heights are slightly increasing since 1881 ($\bar{x}$ = 803.7 ; σ = 133.8, Kendall's tau = 0.12).This rising trend is also found in Spring (Kendall's tau = 0.028) and Winter (Kendall's tau = 0.029). According to the Grosswetterlagen, most of the annual rains are due to westerly and southerly circulations (31% and 22% respectively). In terms of intense rainfall, 34 % and 23 % are caused to southerly circulations and main high / low pressure area over central Europe. More precisely, within the southerly circulations, 32.3% are due to “trough over Western Europe TRW” and “Cyclonic South-westerly SWZ” regimes each. Within the main high / low pressure area over central Europe, 72.2 % are caused by the “Zonal ridge over Central Europe BM” regime. These findings have to be taken with great notice for a sustainable water management because all of them are drastically increasing since 1881 (table 1; fig. 1). This finding is even more worrying on a seasonal scale and more specifically in the summer. Indeed, it is during this season that 78% of the heaviest rains occur and the southerly circulations, TRW, SWZ and BM regimes are all increasing as well (table 1, fig. 2).

In a similar way, the OWTC indicates that the southwest wind direction provoques 61%, 72% and 69% of intense, heavy and long rainfalls, respectively. More sharply, the SWCAW regime (meaning a Southwest Wind direction, Cyclonic near surface, Anticyclonic in the upper atmosphere and a Wet atmosphere) brings 24 %, 35% and 24% of them and it is increasing as well since 1980, on an annual basis and in summer as well (table 1).

In conclusion, the results obtained from both weather types are matching and indicating that the proportions of regimes causing the most intense rainfalls over the Lyon area are steadily increasing. These evolutions in the nature of the synoptic circulations at the origin of the intense rains are to be taken with great attention for an anticipation of techniques and solutions of sustainable water management in urban environment. However, even if these climatic trends are not a priori subject to sudden variations, it remains difficult to predict these circulations in the medium or long term, particularly in the context of current climate change.

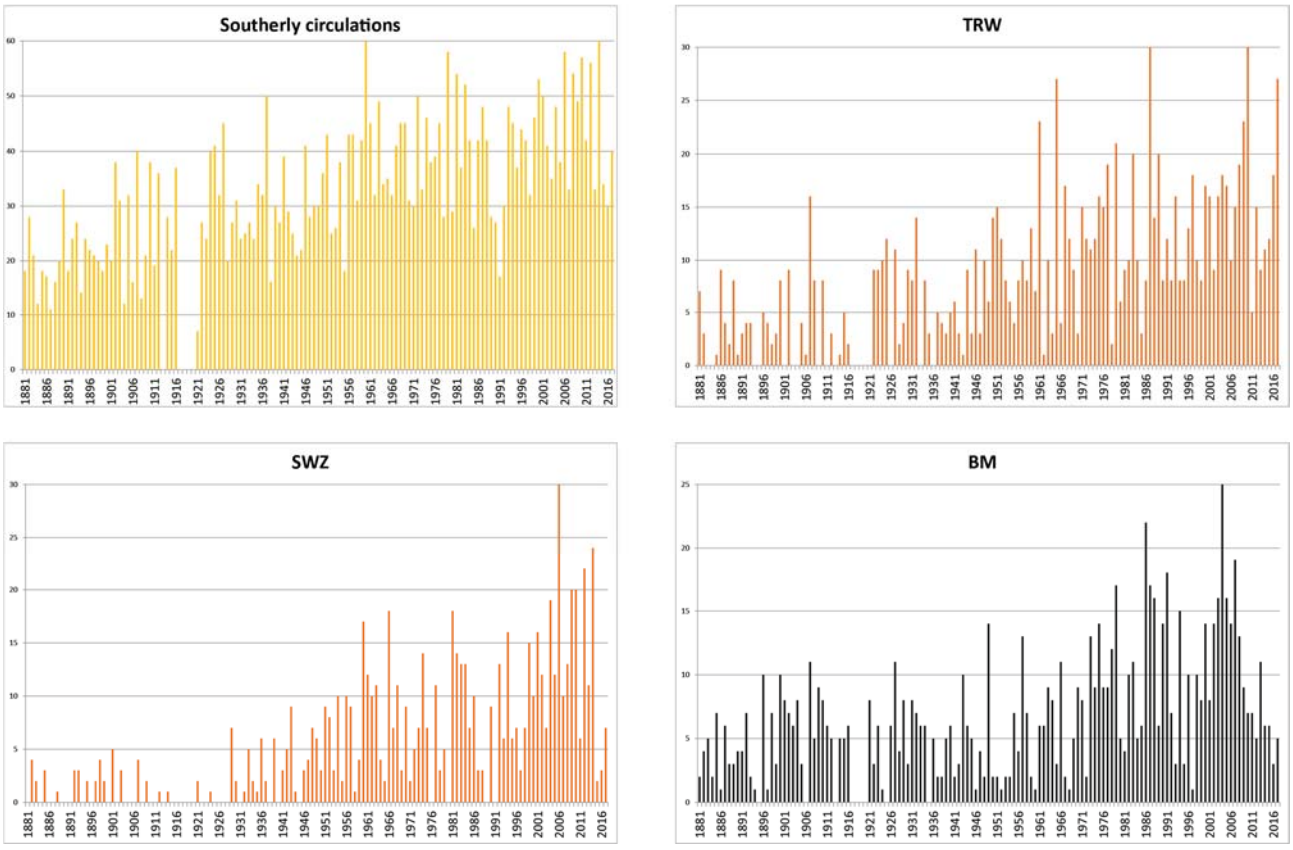

Fig 1: Southerly circulations and TRW, SWZ and BW Großwetterlagen during rainy days on an annual basis in Lyon since 1881

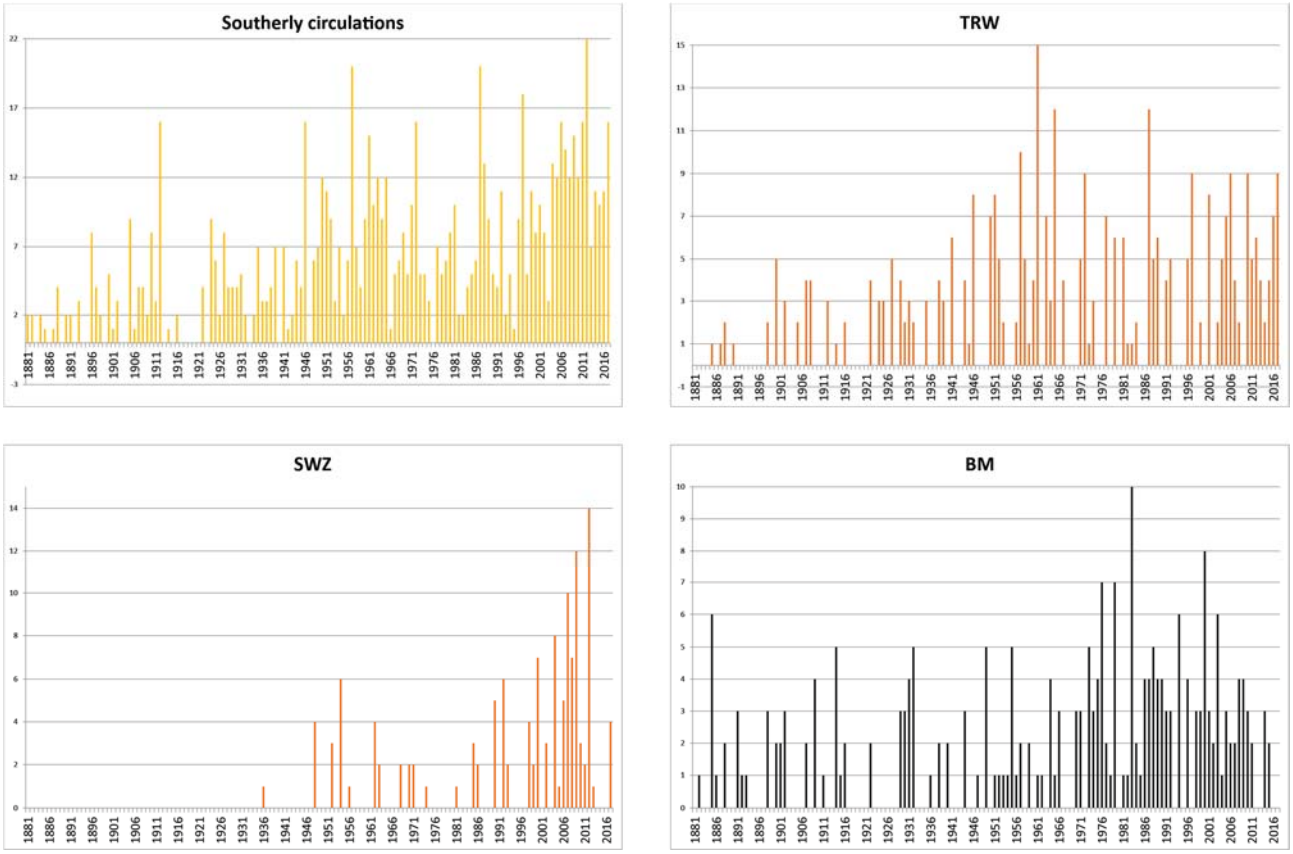

Fig 2: Southerly circulations and TRW, SWZ and BW Großwetterlagen during rainy days in Lyon in Summer since 1881

Tab 1: Kendall's tau for the weather types mainly responsible of intense precipitations in Lyon

	Weather types	Kendall's tau		p-value	
		annual	summer	annual	summer
Subjective Hess-Brezowsky Grosswetterlagen (1881 to 2017)	Southerly circulations	0.477	0.454	<0.001	< 0,001
	Cyclonic South-westerly SWZ	0.501	0.428	<0.001	< 0,001
	Trough over Western Europe TRW	0.470	0.292	<0.001	< 0,001
	Zonal ridge over Central Europe BM	0.280	0.261	<0.001	< 0,001
Objective Weather Type Classification (1980 to 2017)	SWCAW	0.298	0.166	0,005	0,083

REFERENCES

Bissolli, P., Dittmann, E. (2001), The objective weather types classification of the German Weather Service and its possibilities of application to environmental and meteorological investigations, Met. Zeitschr, 10, 4, 253-260.

Gerstengarbe F.-W., Werner P., (1999), Katalog der GroßwetterlagenEuropas (1881– 1998), nach Paul Hess und HelmuthBrezowsky (Catalog of European weather types (1881–1998) after Paul Hess and HelmuthBrezowsky). Potsdam, Germany. 138 p.

James, P. (2007), An objective classification method for Hess and Brezowsky Grosswetterlagen over Europe, Theor. Appl. Climatol., 88, 17-42.

State of World Population 2007 Available online: /fr/node/5923 (accessed on Jul 17, 2018).

Renard F., Lédée B., Langlois W. (2015), Intensification of rainfall related to climate change and its impact on urban water management, Proceedings of Urban Rain15, 10th International Workshop on Precipitation in Urban Areas, Switzerland, 203-207