The Detection of Weekly Preferential Occurrences with an Application to Rainfall

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ABSTRACT

The detection of weekly preferential occurrences in atmospheric and hydrologic processes has recently attracted much attention as a way to identify the signature of anthropogenic climatic changes. The interpretation of previous analyses, however, is not unequivocal, in part as a result of a lack of widely accepted statistical criteria. Here, a general and exact method to detect the presence of weekly preferential occurrences is developed and applied to long rainfall observations in Marghera, Italy; Philadelphia, Pennsylvania; and Portland, Maine. The method makes use of the fact that, under the null hypothesis of stationarity, the process of event occurrence in the different days of the week is equivalent to the random distribution of a number of balls (the wet days) in a set of boxes (the days of the week). The departure from a homogeneous distribution is then characterized through the probability of the maximum number of balls in a box, which can be computed exactly with no ad hoc assumptions. The new method shows that (i) preferential rainfall weekly occurrences emerge in all cases in the most recent period analyzed (1990–2006), while they are absent—or are too weak to be detected—in previous years (before 1989); and (ii) the balls-in-boxes approach appears to be more sensitive than Pearson's test when deviations from homogeneity are associated with just one day of the week, a common occurrence in connection with day-of-the-week effects. The results presented help to reconcile previous contrasting studies and to contribute compelling evidence that anthropogenic changes in the local climate have occurred over the past century in urban and industrial areas.

1. Introduction

Weekly preferential occurrences in atmospheric and hydrologic processes have been identified and studied since the beginning of the past century (Ashworth 1929). More recently, weekly atmospheric cycles have attracted much attention as a way to clearly identify anthropogenic impacts on local and global hydrometeorological cycles and to pinpoint human-induced climate change. Several recent contributions, in fact, have analyzed observations of precipitation (Cerveny and Balling 1998; DeLisi et al. 2001; Dessens et al. 2001; Bäumer and Vogel 2007; Schultz et al. 2007; Bell et al. 2008), temperature (Simmonds and Keay 1997; Coakley 2000; Forster and Solomon 2003; Gong et al. 2006), visibility (Tsai 2005), and of other atmospheric properties (Cerveny and Coakley 2002; Sanchez-Lorenzo et al. 2008; Barmet et al. 2009) in search for preferential weekly occurrences in different geographical areas and over different spatial scales. Conclusions are often not unequivocal, partly because the signature of weekly preferential occurrences, even when it is present, may be affected, and possibly masked, by several factors, such as the observation methodology, the general and local atmospheric circulations, dominant synoptic types, and others. For example, Cerveny and Balling (1998), using satellite rainfall retrievals, find a significant effect of the day of the week on rainfall off the East Coast of the United States. DeLisi et al. (2001) examine rainfall observations from cities in the ''eastern corridor'' and reach the opposite conclusion, that no weekly cycle is detectable. Bell et al. (2008) using Tropical Rainfall Measuring Mission (TRMM) rainfall estimates, too, find a significant increase in rainfall in the second part of the week in the Southeast of the United States. Schultz et al. (2007) analyze a large set of observations from 219 stations in the United States to reach the opposite conclusion, that precipitation amounts and frequency do not exhibit any dependence on the day of the week. In Europe, Bäumer and Vogel (2007) analyze 12 stations in Germany to find significant departures from a homogeneous distribution of rainfall during the week. Franssen (2007) considers rainfall observations from two

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stations in Switzerland to refute the conclusions by Bäumer and Vogel (2007) and to show that random fluctuations can account for observed deviations from homogeneity during the week. Bäumer and Vogel (2008) reply by arguing for the contrary, producing additional information in support of their earlier conclusions.

All these studies differ widely in terms of observation scales and methodologies, but an important source of controversy and ambiguity is the lack of accepted quantitative criteria, devoid of assumptions, to establish when departures from a homogeneous distribution of events during the week may be considered to be significant.

Here, a new and general method to objectively identify the possible preferential occurrence of hydrometeorological "events" during the week is developed. The method makes no assumption as to the underlying probability distributions and uses the probability of occurrence of the maximum number of events in one single day of the week, which is computed exactly, as a measure of departure from homogeneity. The method is compared to the standard Pearson's test by application to three long daily rainfall time series, representative of different climatic regimes and of different potential anthropogenic effects (e.g., due to nearby industrial or urban areas).

2. The chi-square and the balls-in-boxes tests

Here, a "wet day" is defined as any day, say, the i^{th} day in the sequence, for which the daily rainfall amount $h_i \geq h_t$, where h_t is a selected threshold. We wish to test against the null hypothesis that wet days arrive on any day of the week with equal probability $p = 1/7$. Let n_k indicate the number of wet days occurring on the k^{th} day of the week and $n = \sum_1^7 n_k$.

It is quite straightforward to recognize that, under the null hypothesis of a uniform occurrence of wet days during the week, the quantity $\chi^2 = \sum_{k=1}^{7}(n_k - n/7)^2/(n/7)$ has a chi-square distribution with $\nu = 6$ degrees of freedom. Numerical values of χ^2 obtained from a sample can be compared to those corresponding to the desired probability of exceedance/confidence level to construct a hypothesis test. Note that this test equally weights wet-day occurrences during the whole week and is thus sensitive to departures from a uniform distribution of the observational distribution as a whole. Departures from homogeneity related to wet days occurring preferentially on a single day of the week are thus more likely to remain undetected.

To construct a test that can more effectively identify departures from homogeneity due to preferential occurrences on a single day of the week—that is, of the type expected in the detection of the so-called weekend effect (Gong et al. 2006)—one can consider the probability distribution of the number of wet days occurring on the day of the week that exhibits the maximum number of wet days. This means that, rather than considering the probability distribution of the n_k's in its entirety, we only test whether the observed value $m_M = \max_k(n_k)$ is highly unlikely under the homogeneity hypothesis. If the probability of occurrence of a wet day during the week is uniform, then the number of wet days, $n_1, n_2, n_3, \ldots, n_7$, obey a multinomial distribution (Ewens and Wilf 2007),

$$P(n_1, n_2, \ldots, n_7) = \frac{1}{7^n}\frac{n!}{n_1!n_2!\cdots n_7!};$$
$$n_1 + n_2 + \cdots + n_7 = n, \tag{1}$$

where $P(n_1, n_2, \ldots, n_7)$ is the probability distribution of observing the configuration $(n_1, n_2, \ldots, n_7)$ when n "balls" (the wet days) are randomly distributed among seven "boxes" (the days of the week) with equal probability. The probability that no n_k exceeds an arbitrary threshold m is given by (Ewens and Wilf 2007)

$$P(n_1, n_2, \ldots, n_7 \leq m) = P(m, n) = \sum_{\substack{0 \leq n_1, \ldots, n_7 \leq m \\ n_1+n_2+\cdots+n_7=n}} \frac{1}{7^n}\frac{n!}{n_1!n_2!\cdots n_7!}. \tag{2}$$

If M is the day of the week with the maximum number m_M of wet-day occurrences in the observational record, then $P(m_M - 1, n)$ can be used to characterize how exceptional such an observational record is under the homogeneity assumption. In fact, a large $P(m_M - 1, n)$ means that the exceedance of $m_M - 1$—that is, the observation of a number of wet days in a single day of the week greater or equal to m_M—is an unlikely event under the homogeneity hypothesis. Hence, $P(m_M - 1, n)$ represents the confidence level at which the null homogeneity hypothesis can be rejected. The statistical test based on $P(m_M - 1, n)$ will be termed, following Ewens and Wilf (2007), the *balls-in-boxes* method.

Varying the threshold value h_t offers the interesting possibility of investigating departures from a homogeneous distribution for rainfall events of different intensity. In fact, it may be argued that anthropogenic influences (such as aerosol emissions or anomalous heating due to energy consumption) may not alter the probability of occurrence of rainfall events, but that they could, once the general atmospheric circulation is suitable for rainfall occurrence, increase rainfall intensity. In this case, a preferential rainfall occurrence may be expected for events with relatively large intensity, which may be studied by increasing the threshold h_t defining a wet day. Below, the effects of anthropogenic activities on both ordinary and intense rainfall events are studied by exploring thresholds 0 mm ≤ h_t ≤ 50 mm at three selected sites: one site in Europe and two sites in the United States.

To identify possible changes in rainfall occurrences due to recent variations in human activities, the balls-in-boxes method and the χ^2 test are applied to the time series available at each study site, as well as to two nonoverlapping subsets representative of "past" and "modern" periods. In fact, in some of the areas where they have been identified, weekly preferential occurrences have been shown to be detectable only in the last few decades (Bell and Rosenfeld 2008). Therefore, the three available datasets in the following section are partitioned with the modern data subsets starting in 1990, which is likely to enhance the probability of detecting weekly preferential occurrences in the modern period if they are present.

3. Results

The earlier-mentioned tests for the uniform arrival of wet days during the week are applied to the daily rainfall data recorded at Marghera (Italy, 1976–2007; available online at http://www.istitutoveneto.it/venezia/dati/atmosfera/dati_entezona/stazione_23/3sdgfe8t5ws.html), Philadelphia (Pennsylvania, 1900–2006; available online at http://www.ncdc.noaa.gov/oa/ncdc.html), and Portland (Maine, 1948–2006; also available on the NCDC's Web site). Marghera was selected because it is the site of a major industrial area, where significant anthropogenic influences on atmospheric processes may be expected, with the possible presence of weekly cycles. Philadelphia was selected because a long series of observations was available there, representative of an area where the presence of weekly cycles had been previously investigated (Cerveny and Balling 1998; DeLisi et al. 2001). Portland was chosen as representative of a second large industrial area with potentially important effects on local atmospheric processes, which had also been considered in previous works (DeLisi et al. 2001).

a. Marghera

The weekly distribution of days with $h > 0$ mm at Marghera is shown in Fig. 1, where the expected number of wet days per day of the week, $E(n_k) = n/7$, computed under the homogeneity assumption, is shown as a reference. Deviations from the expected value are maximum for Mondays, for the analysis on the entire period; for Tuesdays, in the 1976–89 period; and for Saturdays, in the 1990–2006 subperiod. Thus, there seems to be a tendency for the day with the maximum number of wet-day occurrences to move toward the end of the week in the more recent period. Deviations from homogeneity are, however, likely compatible with a stationary occurrence

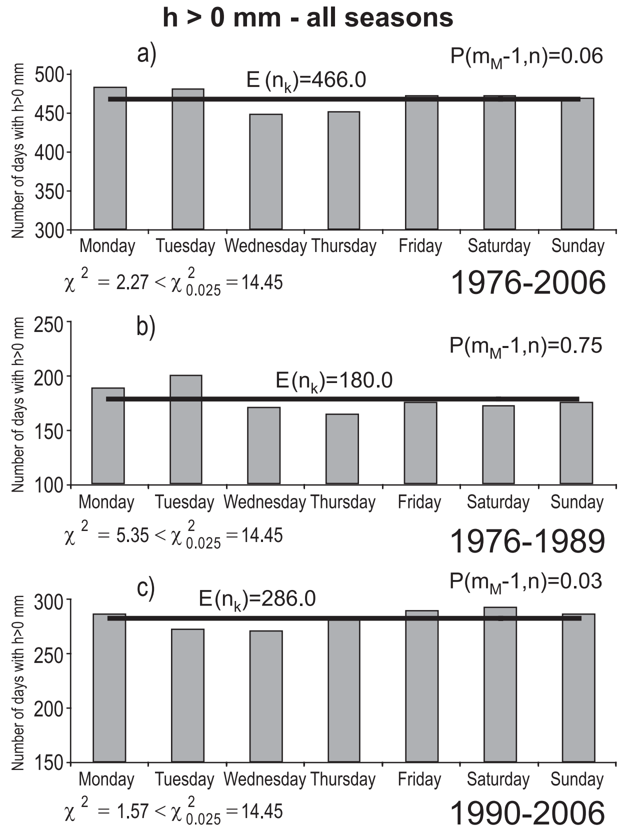

FIG. 1. Frequency distribution of wet-day occurrence $h > 0$ mm during the week in the Marghera time series. No significant departures from homogeneity are detected for (a) the entire 1976–2006 period and for the (b) 1976–89 and (c) 1990–2006 subperiods. The conclusions based on the χ^2 test and the value of the probability of the maximum number of wet days during the week are in good agreement.

of wet days during the week. In fact, computed χ^2 values are quite small and in all cases very far from the threshold value ($\chi^2 = 14.45$) corresponding to the 0.025 confidence level, a strict limit adopted to reduce the possibility of unfoundedly rejecting the homogeneity hypothesis. Pearson's test thus accepts the homogeneity hypothesis in all cases.

The balls-in-boxes approach also indicates a negligible departure from homogeneity. The probability of occurrence $P(m_M - 1, n)$ of a maximum number of wet days in one day of the week smaller than the observed m_M is, in fact, quite small [$P(m_M - 1, n) = 0.06$ for the entire observation period; $P(m_M - 1, n) = 0.75$ for the 1976–89 subperiod; and $P(m_M - 1, n) = 0.03$ for the 1990–2006 subperiod]. This means that it is very likely under the homogeneity hypothesis [probability = $1 - P(m_M - 1, n)$] for the maximum number of exceedances in one day to be even larger than those observed in all the three cases (0.94 for the entire period, 0.25 for the 1976–89 subperiod, and 0.98 for the 1990–2006 subperiod). It should hence be concluded that observed exceedances $h > 0$ mm are highly compatible with a homogeneous arrival of wet days during the week, and the null hypothesis should be accepted.

The presence of preferential occurrences of wet days for different rainfall intensities was tested, as discussed earlier, by exploring an entire range of the threshold defining a wet day occurrence up to $h_t = 50$ mm. A sample result for $h_t = 15$ mm (the case displaying the largest departures from homogeneity as will be seen later) is shown in Fig. 2, where increased departures from homogeneity with respect to the $h_t = 0$ mm case may be seen. Also for these more intense events the computed χ^2 values are well below the critical value for the chosen level of significance in all cases. According to the balls-in-boxes test the probability of occurrence of a maximum number of wet days during the week smaller than the observed one is, again, relatively small in all cases [$P(m_M - 1, n) = 0.81$ is the highest value, for the 1978–89 subperiod], indicating that observed departures are not exceptional. One must thus, again, conclude that Pearson's test and the balls-in-boxes method do not detect significant departures from a homogeneous distribution. This is valid for the entire observation period 1976–2006 and for the two subperiods 1976–89 and 1990–2006.

The possible effects of anthropogenic processes, such as aerosol or heat release, are influenced by the local atmospheric circulation, and the previous literature indicates that preferential weekly occurrences may display seasonality (Simmonds and Kaval 1986). Furthermore, the autumn and winter seasons in northeastern Italy, where Marghera is located, are characterized by interstorm periods between successive large-scale Atlantic stratiform events with typically modest mean advection and a stable vertical atmospheric profile. This is an ideal situation for the progressive accumulation of local releases (e.g., of aerosols or energy), which, on the contrary, are more likely to be dispersed in spring–summer, because of a more frequent occurrence of unstable atmospheric conditions. It is thus interesting to see whether preferential occurrences of rainfall events may be detected when the analysis is restricted to the autumn–winter period. In fact, the analysis on autumn (September–April) observations (Fig. 3) and for $h_t = 15$ mm shows that the modern period exhibits increased departures from homogeneity. The values of χ^2, however, remain below the $\chi^2 = 14.45$ limit and, even though $\chi^2 = 13.17$ for the 1990–2006 period is close to the critical value, Pearson's test narrowly rejects the homogeneity hypothesis at the 0.025 confidence level. The balls-in-boxes approach reaches a different conclusion. While $P(m_M - 1, n) = 0.94$ for 1976–89 (associated to a maximum number of

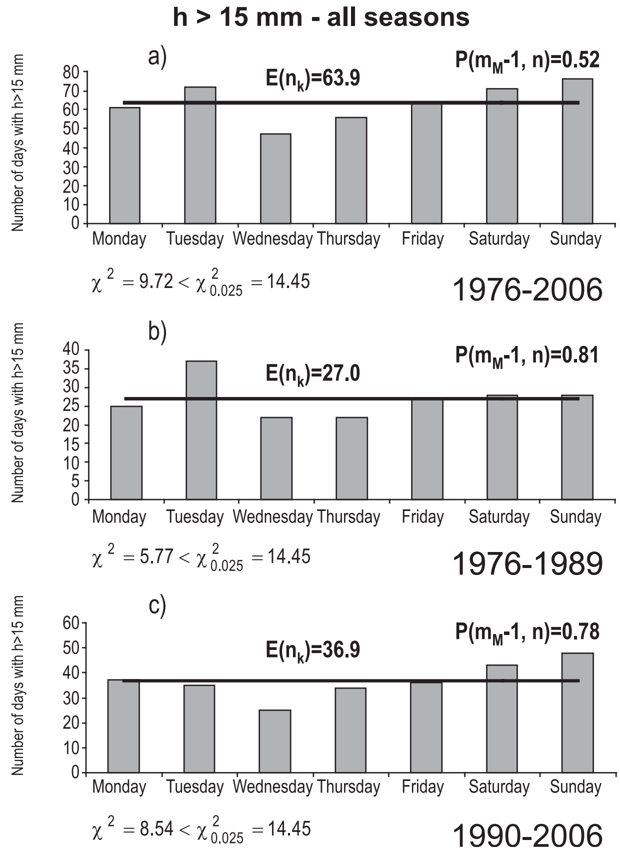

FIG. 2. As in Fig. 1, but with $h > 15$ mm.

wet days $m_M = 17$ for Tuesday, out of a total of 89 days), $P(m_M - 1, n)$ increases to 0.98 for 1990–2006, with a probability of exceeding the observed maximum number of wet days (30 out of a total of 121 days, for Sundays) equal to 0.02. Hence, only 2 out of 100 samples would, on average, display such a large maximum number of wet days in one day of the week if the homogeneity hypothesis were correct. Therefore, it must be concluded that there has been a significant change in the occurrence of wet days during the week after the 1990s, with a more likely occurrence of intense rainfall on Sundays, indicative of a strong anthropogenic influence on the local rainfall regime. Rather than considering a limit value of χ^2 for a fixed significance level, it may be useful to compute the cumulative probability $P(\mathcal{X}^2 \leq \chi^2)$ that directly qualifies the likelihood of the observed wet-day distribution. In fact, the study of the P value associated with the observed χ^2 and of $P(m_M - 1, n)$ as a function of the threshold h_t (Fig. 4) is quite instructive. It is seen that the behaviors of $P(\mathcal{X}^2 \leq \chi^2)$ and of $P(m_M - 1, n)$ versus h_t are quite consistent, and that both Pearson's test and the balls-in-boxes method lead to the conclusion that a preferential occurrence of

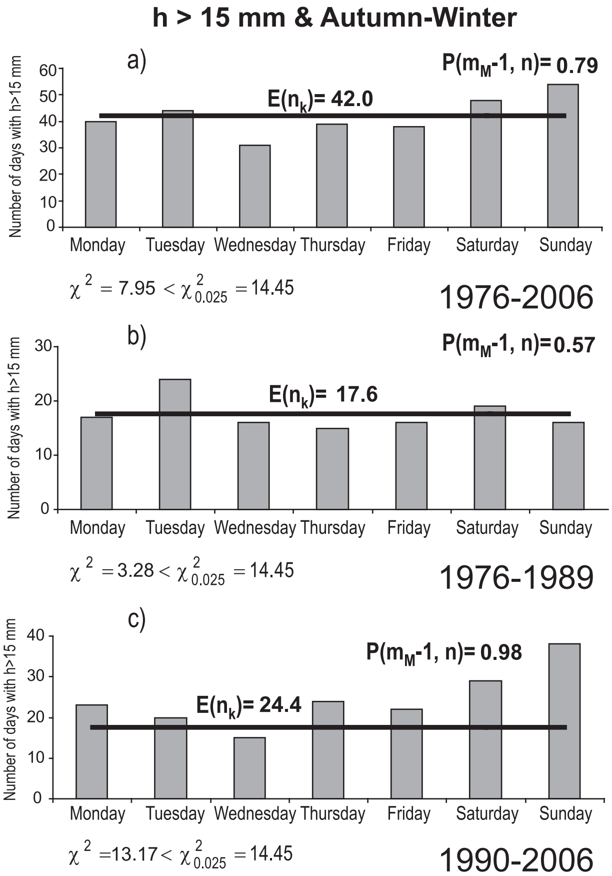

FIG. 3. Frequency distribution of the occurrence of days with $h > 15$ mm during the week in the Marghera time series for the autumn–winter season. The homogeneity hypothesis should be accepted for (a) the entire 1976–2006 period and for (b) the 1976–89 subperiod. Significant departures from homogeneity are detected for the (c) 1990–2006 period by the ball-in-boxes approach but not by the χ^2 test.

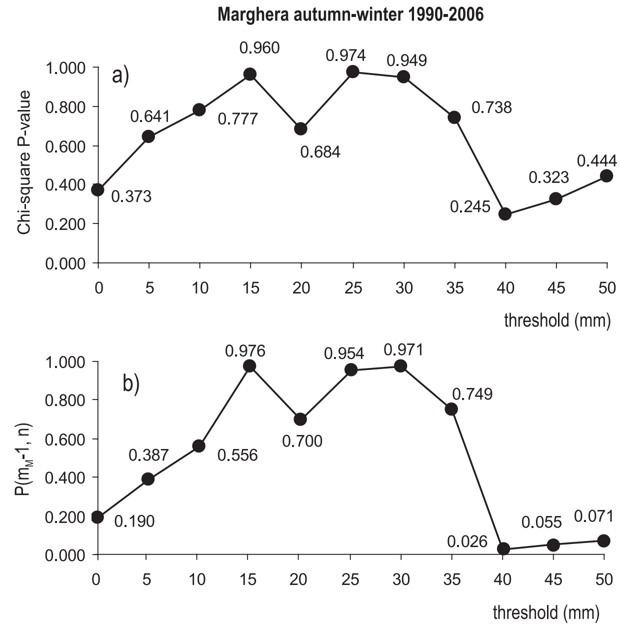

FIG. 4. (a) Cumulative probability according to the χ^2 distribution and (b) probability of occurrence of the maximum number of wet days $P(m_M - 1, n)$ for the Marghera station in the 1990–2006 autumn–winter period. Departures from homogeneity emerge for intermediate values of daily rainfall depth.

wet days during the week indeed exists for intermediate intensities. Low-intensity and extreme events seem relatively unaffected by human interference in this case.

b. Philadelphia

No preferential occurrence of wet days was detected for Philadelphia in the 1950–2006 observation period as a whole. More refined analyses were then performed for the subperiods 1970–89 and 1990–2006 in search for possible anthropogenic effects in more recent years. Indeed, the period 1970–1989 does not exhibit appreciable deviations from a homogeneous distribution of wet days during the week. Both the χ^2 test (at the 0.025 confidence level) and the value of the probability $P(m_M - 1, n)$ confirms that the observed wet-day distribution is very likely a realization of a uniform distribution (Fig. 5a). The analyses on the 1990–2006 period yield contrasting conclusions: while Pearson's test supports the acceptance of the null hypothesis of a homogeneous distribution, the value $P(m_M - 1, n) = 0.97$ is quite significant and strongly suggests a preferential occurrence of wet days on Fridays (Fig. 5b). The reason for

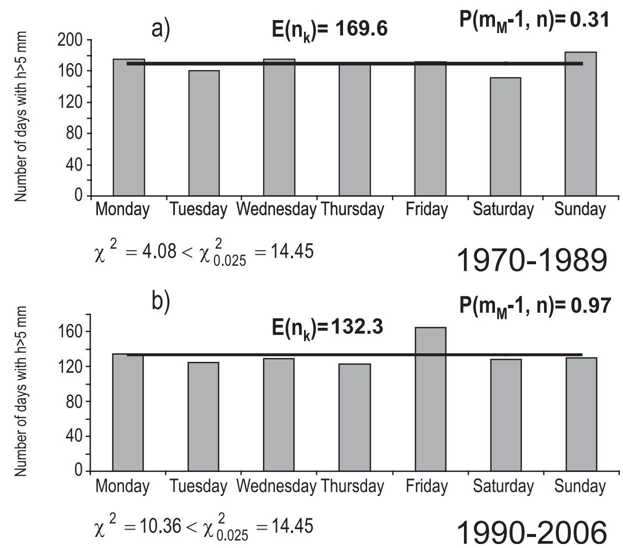

FIG. 5. Frequency distribution of the occurrence of days with $h > 5$ mm in the Philadelphia time series. The χ^2 test accepts the null homogeneity hypothesis both for the (a) 1970–89 and (b) 1990–2006 periods. The value of $P(m_M - 1, n) = 0.97$ for the modern period, however, suggests that a significant departure from homogeneity occurs in this case.

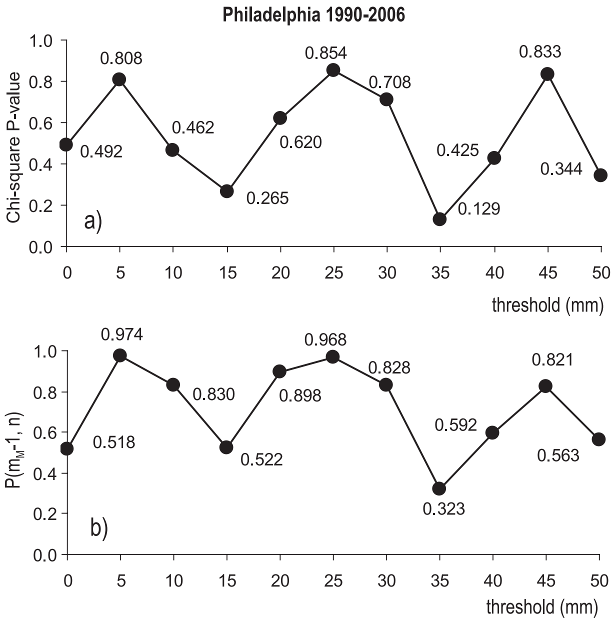

FIG. 6. Cumulative probability $P(\chi^2 \leq c^2)$ according to the c^2 distribution and probability of occurrence of the maximum number of wet days during the week, $P(m_M - 1, n)$, for Philadelphia in the 1990–2006 period. Departures from homogeneity emerge for some values of the threshold rainfall depth according to the ball-in-boxes approach; whereas the χ^2 test suggests that the homogeneity hypothesis should be accepted in all cases.

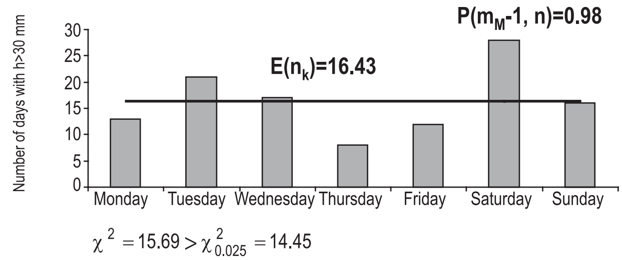

FIG. 7. Frequency distribution of the occurrence of days with $h >$ 30 mm during the week in Portland for the 1990–2006 period. The null homogeneity hypothesis is rejected both according to the χ^2 test and to the low probability of occurrence of the observed maximum number of wet days during the week.

the different results obtained with the two methods may be sought in the fact that departures from homogeneity are manifested in a frequency anomaly in just one day of the week, whereas the observed wet-day frequencies are approximately homogeneous for the rest of the week. The χ^2 test measures "average" deviations from homogeneity and is thus relatively insensitive to the departures seen here. On the contrary, the method based on the maximum number of wet-day occurrences in a single day of the week specifically addresses the departures from homogeneity in a single day and is thus most sensitive to this situation. Support of the existence of a preferential occurrence of rainfall events also comes from analyses of different thresholds defining a wet day (Fig. 6). In fact, the preferential occurrence pattern persists for several values of the threshold, showing that this is a robust feature of medium-intensity events in Philadelphia, rather than an occasional and insignificant fluctuation.

c. Portland

Data from Portland cover the period 1970–2006. As before, two nonoverlapping subperiods were considered to detect possible differences in rainfall weekly regimes. No preferential occurrence of rainy days is identified for the 1970–89 period. On the contrary, the χ^2 test and the probability of the maximum number of wet days during the week $[P(m_M - 1, n) = 0.98]$ agree that there is a significant departure from a homogeneous occurrence (Fig. 7). In this case there is a general departure of the overall frequency distribution from a uniform distribution, which is captured both by the χ^2 test and by an analysis of the maximum number of wet days. Saturday is the day of the week that displays the maximum number of wet-day occurrences for all the thresholds but for $h_t = 0$ mm (for which the largest number of wet days occurs on Wednesday) and $h_t = 20$ mm (Tuesday). Notably, $h_t = 0$ mm and $h_t = 20$ mm correspond to minima for both $P(X^2 \leq \chi^2)$ and $P(m_M - 1, n)$ (Figs. 8a,b) and

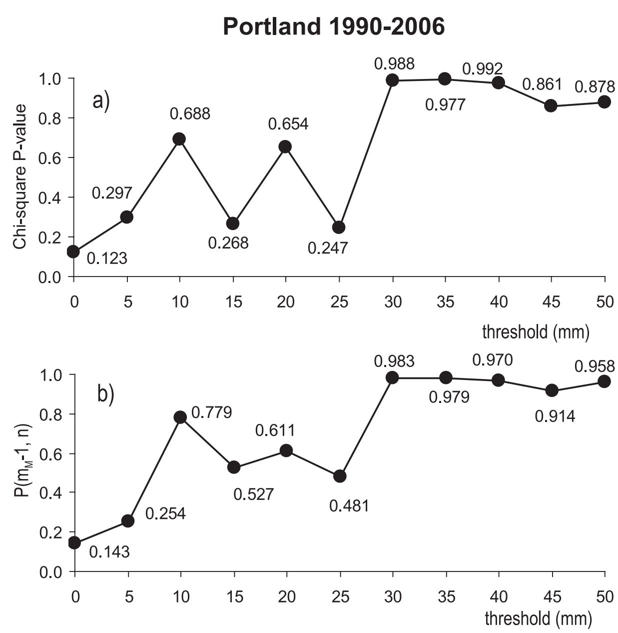

FIG. 8. Cumulative probability $P(\chi^2 \leq c^2)$ according to the c^2 distribution and probability of occurrence, $P(m_M - 1, n)$, for Portland in the 1990–2006 period. Departures from homogeneity emerge for several large values of the threshold rainfall depth according to both the statistical tests considered.

are thus very likely associated with random fluctuations in a homogeneous occurrence process of events above these thresholds. Significantly, a preferential occurrence of wet days during the week emerges most clearly for intense rainfall events and remains highly probable even for the largest thresholds explored—quite differently from the previous applications. This also implies that extreme events are significantly affected by human activities in Portland.

4. Discussion and conclusions

A new method was introduced to test for departures from a homogeneous distribution of wet-day occurrences during the week based on the balls-in-boxes problem. The new approach uses an exact expression of the probability distribution of wet-day occurrences and does not rely on simplifying assumptions (e.g., on the form of the probability distribution of the underlying random variables), thus overcoming the limitations of some of the statistical methods traditionally used to assess the possible presence of weekly preferential occurrences (e.g., Barmet et al. 2009).

Significant departures from a homogeneous distribution of wet days are found in all the time series considered, with wet days more likely occurring in the later part of the week. Such departures, however, are not always easily detected, as they may be masked by seasonality and rainfall intensity effects if inappropriately analyzed. In the case of Marghera, for example, a weekly preferential occurrence only emerges under specific atmospheric conditions and when medium-high intensities are investigated, whereas in Portland day-of-the-week effects are detectable just for high-intensity events.

The study of the probability of occurrence of the observed maximum of wet days during the week as a function of the threshold used to define the wet days is found to increase the sensitivity of the statistical analyses. The coherence of results obtained throughout a range of threshold values considerably adds to the robustness of the analyses and reduces the possibility of erroneous conclusions—for example, due to random large deviations from homogeneity for a single value of the threshold.

Weekly preferential occurrences emerge evidently in the most recent period analyzed (1990–2006) at all the three sites considered, while they are not present—or are too weak to be detected—in previous years (before 1990). This circumstance strongly suggests that the effects identified are the result of intensifying anthropogenic influences through processes taking place in expanding urban or industrial areas. The identification of the specific physical processes responsible for the observed intensification of rainfall in the later part of the week is not obvious. For example, aerosols have been shown to affect rainfall processes in a large number of modeling and observational studies, but they are found to favor or inhibit rainfall depending on atmospheric conditions (Rosenfeld 2006; Bell et al. 2008). Other authors have related day-of-the-week effects to heat release connected to human activities (Simmonds and Keay 1997; Bell et al. 2008). Obviously, statistical methods alone cannot elucidate the physical processes responsible for the detected effects. However, they can provide, once their effectiveness and reliability have been established, the sound experimental basis required for clear physical interpretations. Anthropogenic effects on rainfall processes in all the cases analyzed do not affect the occurrence of rainfall events (i.e., the exceedance of $h_t = 0$ mm), they but significantly affect the occurrence of relatively intense events. These results suggest that, whether aerosols or other anthropogenic emissions are responsible for observed day-of-the-week effects, they are not capable of inducing more frequent precipitation events but can promote higher rainfall intensities, in agreement with previous modeling evidence and physical interpretations (Rosenfeld 2006).

When preferential occurrences are found, they tend to occur near the end of the week (Friday in Philadelphia, Saturday in Portland, and Sunday in Marghera). If this phenomenon is indeed related to aerosol build up, it may be explained by assuming that aerosols can detectably affect rainfall processes only when their concentration exceeds a threshold range. Aerosol accumulation during the week would thus be necessary before preferential occurrences may appear. After a rainfall event, aerosol concentrations would again be reduced and the build-up process could start over again. It would, on the contrary, be difficult to explain the observed preferential occurrences in the later part of the week if aerosols acted as inhibitors of rainfall events, as suggested by some of the previous literature (e.g., see discussion in Schultz et al. 2007). The present findings thus support, even though in an indirect and somewhat speculative manner, the rainfall-inducing role of aerosol emissions in the cases examined.

At the Marghera site, it appears that human emissions are significant only under stable atmospheric conditions (which may, e.g., enhance aerosol accumulation), and for medium-intensity events. More intense events are controlled by large-scale factors and do not show weekly preferential occurrences. At the Portland site, preferred weekly occurrences are present for intensities exceeding $h_t \geq 30$ mm day^{-1}, while in Philadelphia this happens for intermediate intensities. The fact that preferential weekly occurrences are only detectable under quite specific conditions may thus explain why some of the previous analyses at these sites did not identify their presence (DeLisi et al. 2001).

The test based on the balls-in-boxes method is, by construction, most sensitive to departures from homogeneity due to anomalies in the occurrence of rainy days in a single day of the week. The application to the Philadelphia site well exemplifies a situation in which the χ^2 test does not reject, at the high 0.025 confidence level, the homogeneity assumption. In fact, the P value associated with the χ^2 values computed from observations does not exceed $P = 0.85$ for any intensity, suggesting that, on average, 15 out of 100 samples extracted from a homogeneous distribution of wet days during the week exhibit a similar or a larger deviation from homogeneity. On the contrary, the use of the balls-in-boxes approach clarifies that only 3 out of 100 samples extracted from a homogeneous distribution, on average, exhibit a number of wet days in a single day of the week that is larger than observed for $h_t = 5$ mm and $h_t = 25$ mm, thus strongly supporting the presence of preferential wet-day occurrences. This suggests the usefulness of a statistical test based on the balls-in-boxes approach and the possibility that effects of the day of the week on rainfall may remain undetected if an appropriate ''magnifying glass'' is not used. The adoption of an adequate statistical approach, such as the method proposed here, can thus decisively contribute to the reconciliation of the contrasting results obtained by Cerveny and Balling (1998), DeLisi et al. (2001), Schultz et al. (2007), and Bell et al. (2008) in the same geographical area covered here and point to the rejection of the homogeneity hypothesis.

The analysis approach adopted, which also accounts for possible seasonal and rainfall intensity effects, contributes compelling evidence that anthropogenic changes of the local climate are indeed possible and have been occurring in recent years. Weekly preferential occurrences are identified, at the different sites considered, for both ordinary and extreme events. A conclusion as to whether rainfall displays weekly preferential occurrences on continental-to-global scales requires an extensive study of a large number of suitably distributed locations. The present contribution clarifies how such a global-scale analysis may be performed to ensure the robustness of the inferences and to overcome the contrasting conclusions of the past.

Lastly, it is worth noting that the balls-in-boxes approach adopted here can be extended, with modest or no adaptation, to the search of weekly preferential occurrences in any hydro-meteorological process, thus making it a tool of potentially wide interest.

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