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Analysis of dry and wet spells from 1870 to 2000 in four Italian sites

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1 Introduction

A public interest on climatic change has risen sharply in recent years. Changes in weather have been also related to a worldwide increase of extreme events. A recent analysis by Dai et al. (1998) shows increases in the overall areas of the world affected by either drought and/or excessive wetness. This work concerns climate extreme events due to very long sequences of dry days. In particular, we investigate a model which is able to fit the observed data and, under the hypothesis that a change has occurred in the last 30 years, we point out eventual different features of the spell distribution between two periods: 1970-2000 compared to the previous secular period (1860-1970).

2 Data and Method

The analysis has been carried out on precipitation data surveyed in 4 Italian cities: Milano, Bologna, Roma and Palermo. Time series of daily precipitation data are from 1860 to 2000 and they are complete, except for Palermo which is 99%. Milano and Bologna are situated at the north of Italy, where the climatic features are similar to continental ones while Roma and Palermo have a typical Mediterranean climate. Year has been divided into two semesters: “summer season” (from April to September) and “winter season” (from October to March), taking into account the Italian seasonable weather. Moreover, we have considered as rainy day the one with a measure equal or higher than 1 millimetre of rain.

2.1 A model for dry and wet spell

The first part of the work has been aimed to find the probability distribution most appropriate to describe dry and wet spells.

At mean latitudes, the rainfall meteorological systems have an average length that goes from one hour (stormy cells) to several days (front perturbation, extra tropical cyclone) while the lack of rainfall is associated to anticyclone systems that can last from one day (intercyclone, anticyclone) to many days (semi permanent or seasonal anticyclone). Therefore, dryness or rainfall of a day affect the following day or the following period, that is the events are dependent although there's a subsequent decrease of this influence.

Several distribution have been applied and the most suitable are: Negative Truncated Binomial distribution and Eggemberger-Polya distribution. The latter is commonly used to model weakly dependent events and it is also preferable to the former by virtue of requiring fewer parameters to be estimated. The Eggemberger-Polya distribution is:

$$p(x) = \frac{d^x}{(1+d)^{h/d+x}} \frac{\Gamma(h/d+x)}{x!\Gamma(h/d)}$$

where Γ is the Gamma function.

In practice, it can be used an application as follows, according to Berger (1983). Defining k as the number of consecutive days of which a spell is composed, then we have:

$$p(1) = \frac{1}{(1+d)^{m/d}}$$

$$p(k) = \frac{m+(k-2)d}{(k-1)(1+d)} p(k-1) \quad k \geq 2$$

with

$$m = \bar{k} - 1$$

$$d = s^2 / m - 1$$

where $\bar{k}$ and s^2 are respectively the average and variance of sequences' length.

The statistic test of χ^2 at 95% of confidence has also carried out to verify if data generated by the model have a good fit to observed ones.

2.2 A model for very long dry spells

In relation to data at our disposal, the Eggemberger-Polya distribution is a good model for describing the persistence of consecutive rainy/dry days under the circumstances that its application requires the class of longest spells to be grouped into a wide bin. Then, we focus the attention on this class in order to deepen an important aspect of precipitation frame like extreme events and, particularly, we apply the Generalised Pareto distribution on longest dry spells.

For the sake of simplicity, let us see a brief description of this model and see Coles (2001) for a complete theory of statistical modelling of extreme values. Let X_1, X_2....... be a sequence of independent and identically distributed random variables, having marginal distribution function F. Fixing a threshold u,we can regard as extreme those determinations $\{x_i : x_i > u\}$ and consider the exceedances $y_j = x_{(j)} - u$. It follows that the stochastic behaviour of extreme events is given by:

$$\Pr\{X < u + y\,|X > u\} = \frac{F(u+y)}{F(u)} \quad y > 0$$

Obviously F is unknown and then is worth considering an approximation for $n \longrightarrow \infty$,being n the sampling number. We shall leave out other details for the sake of brevity, but if

we opportunely choose a threshold, the distribution function of (X-u), conditional on X>u, will be approximately:

$$H(y) = 1 - \left(1 + \frac{\xi y}{\tilde{\sigma}}\right)^{-1/\xi}$$

defined on $\{y : y > 0 \cap (1 + \xi y/\tilde{\sigma}) > 0\}$

where $\tilde{\sigma} = \sigma + \xi(u - \mu)$ is the modified scale parameter and ξ the shape parameter.

Threshold's choice is usually done by applying a specific methodology, in practice we adopt a threshold corresponding to the 90˚ centile of each data series, with respect to climatic features of different geographical sites. Furthermore, we eliminate the shortest of two spells separated just by one wet day, in order to respect the condition of events to be independent.

2.3 Analysis of a possible change over the last 30 years

We divide time series into two sub-period: 1860-1970 and 1970-2000 under the hypothesis that a climatic change has occurred in the last 30 years. Then, we apply models described above to find some evidence of a change both in the whole distribution of wet/dry spells and extreme dry spells distribution. With regard to the whole distribution of wet/dry spells, the method consists of generating data by Eggemberger-Polya distribution related to first sub-period, using parameters of Eggemberger-Polya distribution applied on the second sub-period. The comparison between generated data and first period empirical data has been carried out thorough χ^2 test.

With regard to extreme dry spells distribution, Kolmogorov-Smirnov test has been applied comparing data generated by Generalised Pareto distribution both for the first and second sub-period.

3 Conclusion

The principal results are as follows:

1. Eggemberg-Polya and Truncated Negative Binomial distribution are more efficient than the other models in fitting observed data both for Wet/Dry spells and annual/seasonal aggregations;

2. Generalised Pareto Distribution (GPD) is a good fit of very long dry spells which we consider as extreme events;

3. Dry and Wet spells distribution don't show any difference between the last 30-years and the secular series, except for five cases with no seasonal or localised regularity;

4. During the last 30-years and for the whole of the stations, the probability of an "extreme" dry spell has increased in wintertime, i.e. the season in which the total precipitation amount is considerable.

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