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CHANGES IN OCCURRENCES OF METEOROLOGICAL EXTREME EVENTS. CASE STUDY: BRAZILIAN MAIN CITIES.

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INTRODUCTION.

Extreme weather and climate events have received increased attention in the last few years, due to the often large loss of human life and exponentially increasing costs associated with them. Variations and trends in extreme climate events have only recently received much attention. The increasing of economic losses, coupled with an raise in deaths due to these events, have focused attention on the possibility that these events are increasing in frequency. One of the major problems in examining the climate record for changes in extremes is a lack of high-quality, long-term data. In some areas of the world augments in extreme events are apparent, while in others there appears to be a decline. Based on this information increased ability to monitor and detect multidecadal variations and trends is critical to begin to detect any observed changes and understand their origins. Since climate extremes can be defined as large areas experiencing unusual climate values over longer periods of time (*e.g.*, large areas experiencing severe drought), one way to investigate trends in climate extremes over time is to develop indices that combine a number of these types of measures (factors).

The analysis of extreme meteorological events indicates that there has been a sizable change in their frequency in Brazil. This suggests that natural variability of the climate system could be the cause of the recent changes, although anthropogenic forcing due to increasing greenhouse gas concentrations cannot be discounted as another cause. It is likely that anthropogenic forcing will eventually cause global increases in extreme precipitation, primarily because of probable increases in atmospheric water vapour content and destabilization of the atmosphere. Relatively little work has been completed related to changes in high frequency extreme temperature events such as heat waves, cold waves, and number of days exceeding various temperature thresholds. In this work trends in the number of warm days in Brazil and changes in the aestival season length are investigated. Significant trends to fewer extreme minimum cold days and also trends to fewer warm maximum temperatures as well are analysed. Apparent temperature, which combines temperature and humidity effects on the human body, is another important measure.

Short-duration extremes' episodes (heat or cold waves) are often responsible for the major impacts on health. Conversely, the location, timing, and magnitude of local and regional changes remain unknown because of uncertainties about future changes in the frequency and intensity of meteorological systems that cause extreme precipitation. There is still much work to be done in determining whether significant large-scale changes in these types of events cause significant impacts in Brazil and around the globe. One of the biggest problems in performing analyses of extreme climate events and if these changes are consistent with what should be expected in the future is the lack of established definitions for what constitutes an extreme. This lack of consensus and a lack of access to high quality, long-term climate data for many parts of the world, with the time resolution appropriate for analyzing extreme events likely means it will be difficult to determine if extremes have changed, and how they may change in the future (climate change scenarios).

Most climate impact studies rely on changes in means of meteorological variables, such as temperature, to estimate potential climate impacts, including effects on agricultural production. However, extreme meteorological events, say, a short period of abnormally high temperatures, can have a significant harmful effect on crop growth and final yield. The characteristics of daily temperature time series, specifically mean, variance and autocorrelation, are analyzed to determine possible ranges of probabilities of certain extreme temperature events with changes in mean temperature of the time series.

The relationships between changes in mean temperature and the corresponding changes in the probabilities of extreme temperature events are quite nonlinear, with relatively small changes in mean temperature sometimes resulting in relatively large changes in event probabilities. These changes in the probabilities of extreme events need to be taken into consideration in order to obtain realistic estimates of the impact of climate changes such as increases in mean temperature that may arise from increases in atmospheric carbon dioxide concentration.

EMPIRICAL CLUSTER ANALYSIS

In this work one analysis the persistence feature of extreme temperature attributes taking into account daily records of the long-term time period over 50 years (1951-2000) of twenty-six typical meteorological data series covering the Brazilian territory.

One uses clustering of variables to classify the uncertainty associated to the grouping process. Notice that this technique may give new variables that are more intuitively understood than those found using principal components. This procedure is an agglomerate hierarchical method. The final grouping of clusters (also called the final partition) is the grouping of clusters which will, hopefully, identify groups whose variables share common characteristics – regional climatology.

Fig.1a: Brazil Political Map.

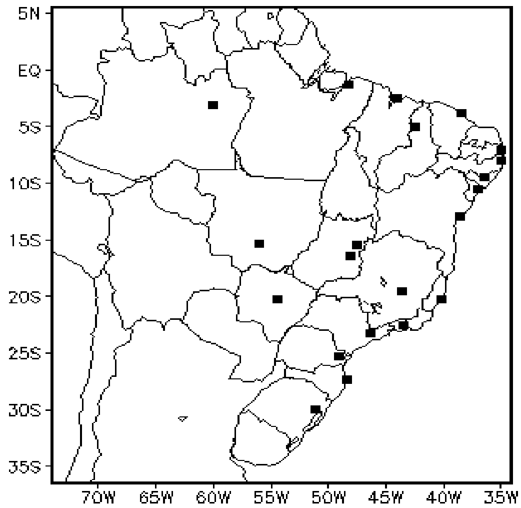
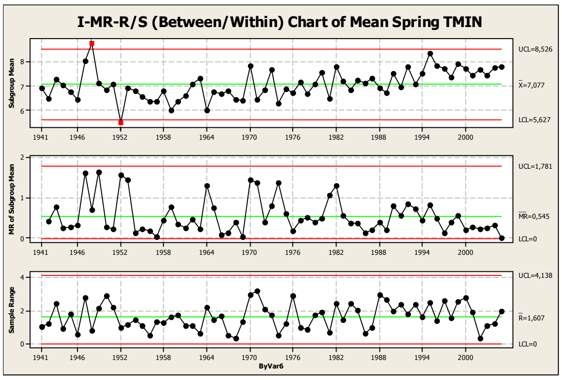


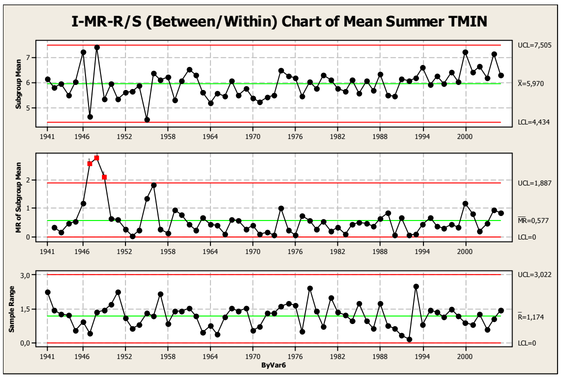
Fig.1b: Target (main) Cities.

The decision about final grouping is also called cutting the dendrogram. The complete dendrogram (tree diagram) is a graphical depiction of the amalgamation of observations or variables into one cluster with 90% of probability to detect the true effect. The similarity level at any step is the percent of the minimum distance at that step relative to the maximum inter-observation distance in the data. The pattern of how similarity or distance values change from step to step can help us to choose the final grouping. The step where the values change abruptly may identify a good point for cutting the dendrogram. The dendrograms displays suggest variables which might be combined, perhaps by averaging or totalling. The regional TMIN ensemble and TMAX ensemble measurements are similar and combine spatial (geographic) characteristics.

Extreme climatic events are those that are rare both in their intensity and in the frequency of their occurrence. Extreme weather and climate events have received increased attention in the last few years, due to the often large loss of human life and exponentially increasing costs associated with them. Variations and trends in extreme climate events have only recently received much attention. The increasing of economic losses, coupled with an raise in deaths due to these events, have focused attention on the possibility that these events are increasing in frequency.

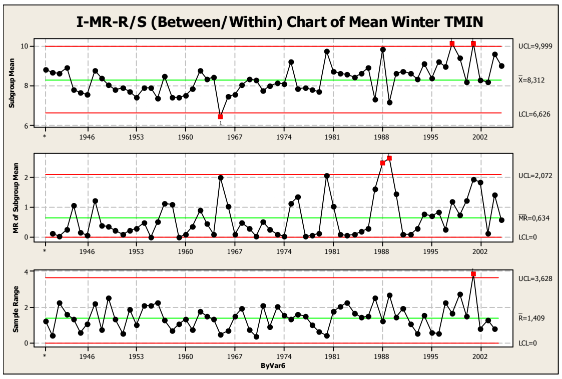


Spring: TMIN for the Northeast Region.

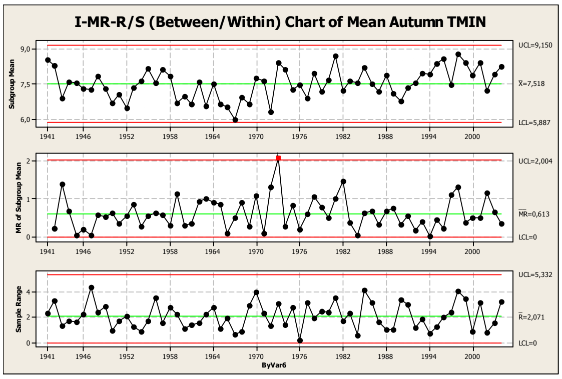


Summer: TMIN for the Northeast Region.

One of the major problems in examining the climate record for changes in extremes is a lack of high-quality, long-term data. In some areas of the world augments in extreme events are apparent, while in others there appears to be a decline. Based on this information increased ability to monitor and detect multidecadal variations and trends is critical to begin to detect any observed changes and understand their origins. Since climate extremes can be defined as large areas experiencing unusual climate values over longer periods of time (e.g., large areas experiencing severe drought), one way to investigate trends in climate extremes over time is to develop indices that combine a number of these types of measures (factors).

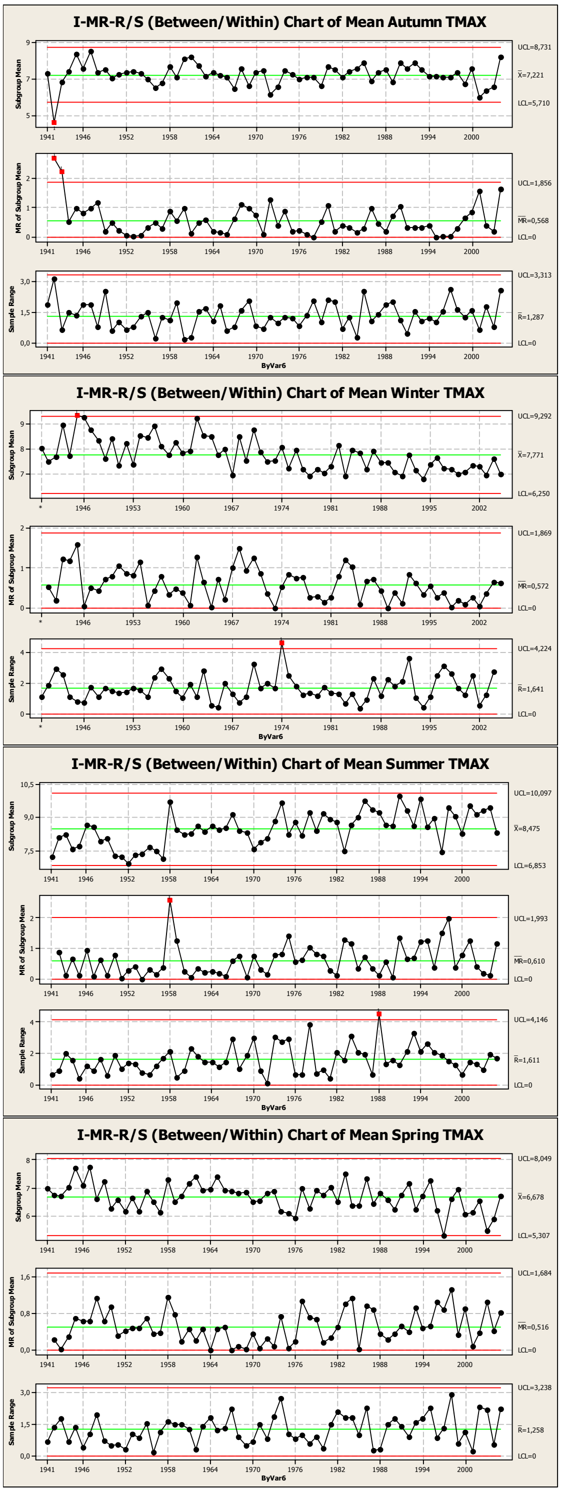


Winter: TMIN for the Northeast Region.



Autumn: TMIN for the Northeast Region.

Short-duration episodes of extreme heat or cold are often responsible for the major impacts on society. Conversely, the location, timing, and magnitude of local and regional changes remain unknown because of uncertainties on future changes in the frequency and intensity of meteorological systems that cause extreme weather and climate events. It is likely that anthropogenic forcing will eventually cause global increases in extreme precipitation, primarily because of probable increases in atmospheric water vapour content and destabilisation of the atmosphere. Relatively little work has been accomplished relating changes in high frequency extreme temperature events such as heat waves, cold waves, and number of days exceeding temperature thresholds.



Seasonal TMAX for the South Region.

EXTREME EVENTS

Extreme events occur naturally in physical systems. The same physical processes that are responsible for generating non-extreme events can contribute to the occurrence of extremes. When the distribution of extreme events is considered in the phase space of a system, the extremes are found, by definition, near the edges of the distribution, at least in the directions/variables in which extremes are defined. The analysis of tail behaviour of asset returns is important from the point of view of climate risk management.

Seasonal daily temperature maximum (*TMAX*) and minimum (*TMIN*) have been analysed taking into account the two subsets of annual extreme temperatures, *TMIN* and *TMAX* subdivided into four seasonal attributes: winter, spring, summer and autumn. The most commonly used definition of extreme weather is based on an event's climatologically on exceedances over threshold distribution, the peaks-over-threshold (POT) methodology.

A more recent approach for modelling extreme events is based on so called peak over threshold methods. The Generalised Pareto Distribution (GPD) is widely used for modelling exceedances of a random variable over a high threshold and it has been shown to be one of the best ways to apply extreme value theory in practice. The POT model is based on "*Pickands-Balkema-de Haan Theorem*" that postulates that the distribution of the observations in excess of certain high threshold can be approximated by a GPD.

In the POT model, first a threshold κ is identified to define the start of the tail region. Then the distribution of the *excesses* over the threshold point is estimated with the help of a GPD approximation. Application of POT model requires x_t to be *i.i.d.* and therefore it is crucial to have appropriate specifications of μ_t and σ_t such that x_t is white noise and does not contain any time dependence. We use a pseudo maximum likelihood approach to estimate the parameters of mean and the volatility dynamics of the returns, using Normal distribution for the innovation x_t. Under this methodology, use of normal distribution for the estimation does not imply the assumption of normality for the distribution of x_t.

Under standard regularity conditions (Coles, 2000) the use of Normal distribution would yield consistent estimates even if the underlying distribution is not Normal. Notice that the pseudo maximum likelihood estimators are obtained by maximising the likelihood function associated with a family of probability distributions that may not necessarily include the true distribution of the underlying random variable whose parameters are being estimated. Gourieroux *et al.* (1984) have established that the estimators of the first two moments (of the unknown distribution) based on the linear and quadratic exponential family are asymptotically consistent and normally distributed regardless of the exact form of the true unknown distribution. The normal distribution, being a quadratic exponential family, can provide consistent estimators of the first two moments. Moreover, this estimator is asymptotically Normal.

Having specified an appropriate time series model for each of the series, we extract the standard residuals coming out of the fitted model and use these residuals for estimating the tails of the innovation distribution. The *Pickands-Balkema-de Haan Theorem* offers the GPD as a natural choice for the distribution of excesses (peaks) over sufficiently high thresholds. However, while choosing an appropriate threshold, one faces an unpleasant trade off between bias and variance. Theoretical consideration suggests that the threshold should be as high as possible for the *Pickands-Balkema-de Haan Theorem* to hold good, but in practice, too high a threshold might leave us with very few observations beyond the threshold for estimating the GPD parameters, leading to statistical imprecision and very high variance of the estimates (McNeil and Frey, 2000).

There is no correct choice of the threshold level. Coles, 2001 use the “mean-excess-plot” as a tool for choosing the optimal threshold level and an arbitrary threshold level of 90% confidence level (*i.e.* the largest 10% of the positive and negative returns are considered as the extreme observations). In this paper, we follow a slightly different approach, first estimating the GPD parameters corresponding to various empirical threshold levels of the extreme observations. Then we plot a graph of the estimated parameters and choose the threshold level at which the estimate stabilises. This is a non-parametric way of choosing the optimal threshold level and it is useful when the mean-excess-plot or normal distribution assumption fail. The validity of the thresholds for *TMIN* and *TMAX* have been assessed checking the stability of the maximum likelihood estimates for the re-parameterised models.

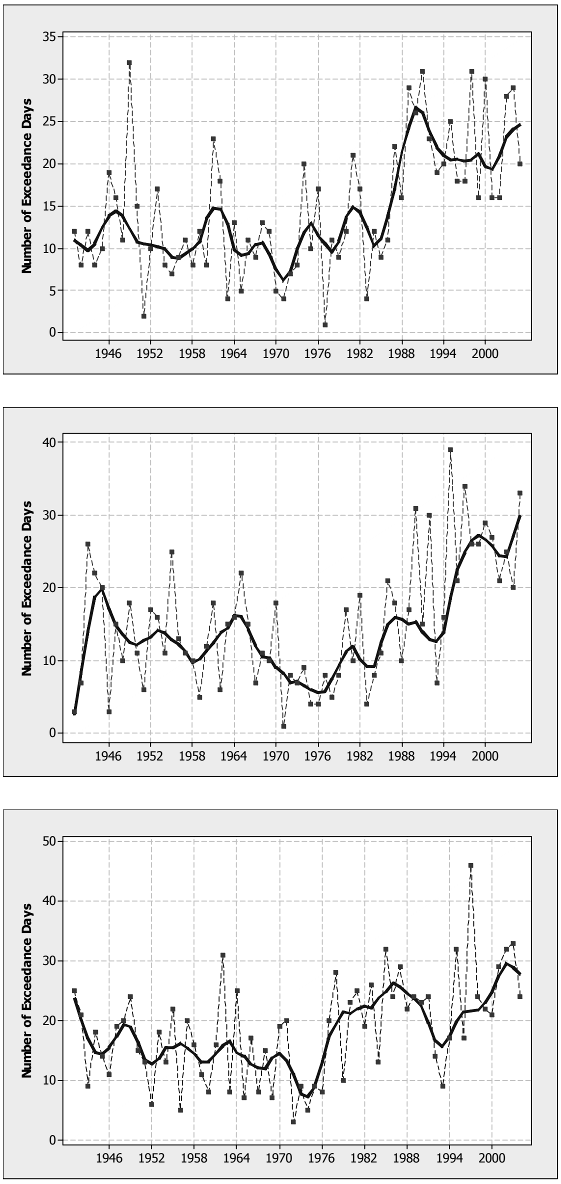
SUMMARY

Like the exponential distribution, the GPD is often used to model the tails of another distribution. However, while the Normal distribution might be a good model near its mode, it might not be a good fit to real data in the tails and a more complex model might be needed to describe the full range of the data. The GPD allows a continuous range of possible shapes that includes both the exponential and Pareto distributions as special cases. The empirical distributions focused in this study lead to a negative shape parameter, whose tails are finite.

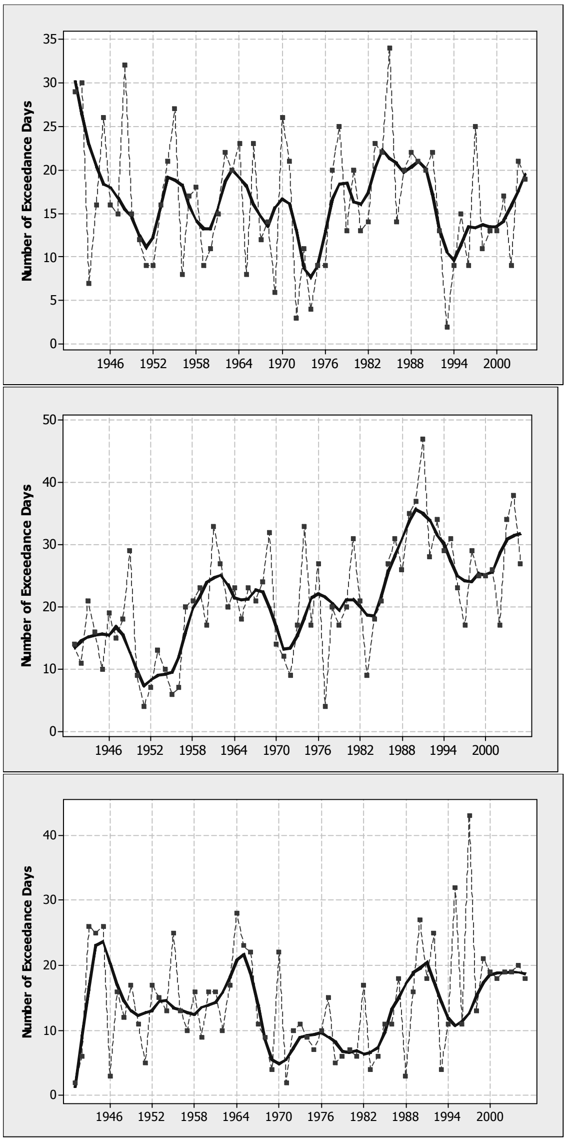
The profile log-likelihood surface (Coles, 2001) for the 10-year return shows “irrelevant” asymmetry, leading to confidence intervals that can be considered symmetric about the maximum likelihood estimate, reflecting the slight degree of uncertainty about large values of each seasonal process.

Observed extreme weather events have a profound impact both on society and on natural processes surrounding the atmosphere, often making a disproportionately large impact. The number of warm nights is increasing on spring, summer and autumn! The number of warm days is increasing on summer! Almost certainly the summer nights are “contaminating” the spring nights and the autumn nights!

The analysis of extreme meteorological events indicates that there has been a sizable change in their frequency in Brazil. This suggests that natural variability of the climate system could be the cause of the recent changes, although anthropogenic forcing due to increasing greenhouse gas concentrations cannot be discounted as another cause. The long-term trend detected for *TMIN* and *TMAX* in Brazil indicates that the magnitude of the air-temperature for the winter, spring, summer and autumn are increasing. The annual trend are carefully analysed and probably the summer is "invading" or "contaminating" spring and spring is "invading" or "contaminating" winter in the Brazilian territory.



TMIN: Spring – Summer – Autumn.



TMAX: Spring – Summer – Autumn.

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