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THE RELATIONSHIP BETWEEN THE NUMBER OF INCIDENCE OF DEATHS CAUSED BY CARDIOVASCULAR DISEASES AND THE CLIMATIC CONDITIONS IN AVEIRO, PORTUGAL

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1. INTRODUCTION

The recognition that human health is closely connected up to daily or seasonal weather conditions have been known even before the written history. Nowadays the existing relationship has been science established beyond doubt, concerning many ailments in particular, or even in the worst case, the weather extremes relation to mortality rates or the weather conditions change to sickness, up to deaths over populated areas.

Thompson et al. (1996) analyzed the occurrence of infarcts of myocardium, over a population of 2254 patients, and they showed up cold weather conditions having stronger effect on male (M) population then female (F), particularly when aging between 50 and 70 years due to their sensitiveness to high humidity effects. Baibton et al. (1977) and Thompson et al. (1996) concluded that there is, probably, a direct effect of the temperature on cardiovascular system. In a similar line of research Thompson et al. (1996), with patients admitted to a coronary care unit, in Leincaster, during a 10-year period, showed up a similar association with respect to temperature and humidity; with strongest relationship occurring during both, the coldest and most humid time periods of the year. Yamazaki et al. (1997) examined the effect of the hypothermia (frostbite) on carotid baro-receptor-cardiac reflexes in human being. They used the power spectral density analyses to study the cardiac interval variability. The effect of environment temperature on blood pressure, on the other side, has been shown independently for both indoor and outdoor temperature in the studies made by Woodhouse et al. (1993) and Thompson et al. (1996). According with their studies, a 4ºC decrease, in a living room temperature, is associated with a 5 mm Hg rise in the systolic blood pressure, corresponding to a 5 % increase in cardiovascular risk.

The climate change also influences the receptor - the human being. Seasonal variations of some physiological parameters such as the hormonal levels are well known. Along the year the seasonal weather changes may impose conditions or predispose people to be more, or even less, susceptible to some kind of disease, depending on the weather condition as well as the season itself. However, following Driscoll et al., (1985), it seems that the direct effect of the atmospheric elements on humans is probably a minor one when compared to the effect on the transported and the pathogenic. The study was made with focus on an area surrounding the Aveiro city, which is located on the bank of a coast lagoon, known as "Ria", between the mouth of Vouga river and the Atlantic Ocean. It is therefore, on a region of low altitude, with prevailing relatively humid weather condition, close to the sea and with an area constituted by river and sea sedimentary terrain.

2. DATA AND METHODOLOGIES

The clinic data related to mortality in the region of Baixo Vouga, surrounding Aveiro city, were provided by INE (National Statistics Institute). The monthly cardiovascular diseases data used were tabulated with respect to sex and cover the 5 years period, between 1990 and 1994.

The myocardial infarct, vascular brain, arteriosclerosis and some others diseases are also included in the total of circulatory data.

The meteorological conditions observed at the University of Aveiro are considered as representative for gathering the characteristic meteorological conditions delimited in the object of this study region, namely - the region of Baixo Vouga, from where the patients are considered.

The series of meteorological data were collected at Aveiro University. The original meteorological data are daily mean meteorological values. Missing values are represented by values found using an interpolation method similar to the one proposed by Peterson and Easterling (1994). These data were, also, subjected to a proper statistical quality control algorithm and analysis.

The statistical significance determination, of persistence and trend, which are common forms of non-random variations, is the first step toward the physical explanation of climate variations. Following Mitchell et al. (1966), the auto correlation lag-1 do not show any evidence of a significant persistence, since most of time series provided negative values for Mann-Kendall statistics.

The April analysis was particularly selected because it is the month that has, on average, the highest mean, aside from being the most variable, of all circulatory admission rate recorded. To find out which was the climatic condition when the highest admissions number of patients with circulatory system problem was registered, in the hospitals of the district of Aveiro, the daily mean meteorological data of April month were also employed.

To identify the predominant types of April climate, the technique of the empirical orthogonal function (EOF), (Preisendorfer, 1988) was used. The procedure was used to find the variation that explains 80% of the variance and a net of 89% of the studied variables. The scree test, as first proposed by Catell (1066), has

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been applied to determine the optimal number of factors to retain in the analysis.
The factor analysis rotation - varimax normalized option was used to perform a varimax rotation of the normalized loading factor (raw loading factor divided by the square roots of the respective communities).
The rotation was aimed maximizing the variances of the squared normalized loading factor, across variables for each factor; which is equivalent to maximizing the variances in the columns of the matrix, of the squared normalized loading factor.
The EOF analysis was made using the April daily data of the surface pressures and the geopotential height field of 500 hPa. The data is presented in a 2.5 degrees grid, covering the region delimited by 30º to 80ºN latitudes and 60º W to 30ºE longitudes, gathered from reanalysis of the NCEP/NCAR. Daily data from 9:00 AM and 3:00 PM (LST) of the meteorological station, located in the University of Aveiro Campus was also used. The seven variables, of 150 days period, used were: pressure, wind speed and direction, saturation deficit, cloud coverage and temperature off the dry thermometer. These are the main variables indicative for the different types of air mass flow in the atmosphere.
The methodology of McGregor et al. (1999) was used to find out the relationship between the observed climatic variables and the number of entrances in the hospitals due to a circulatory system sickness. The relationship between the original variables and the retained one's are expressed by loading components, which, when squared, are equivalent to the correlation between the component and the original variable. Components loading are used for the physical interpretations of the component. These interpretations are, usually, in the form of the combined atmospheric characteristics of thermodynamic and moisture as well as wind and pressure. Calculation of component scores, given by the product of the loading component and the standard daily meteorological data are, in effect, the new meteorological variable values. To gather the days with similar structures, including their interpretations, the cluster grouping and the weather condition type, the technique established by Font (19083) was used.
The series of climatic variability and cardiovascular mortality have been examined through spectral analysis, to determine the data components, stationarity and the minor frequency of Nyquist variance distribution. The spectral analysis was done applying the fast transformation method of Fourier, usually known as FFT (Fast Fourier Transform) (Priestley, 1981)
The presence of significant statistical periodicity in the data sequence is one of the most important elements to for the physical explanation of the climatic variations, in the sense that, an apparently repetitive tendency of a given sequence of climatic events can be related to processes that present similar cyclic properties The coherence SQ analysis, which is an extension of the spectral analysis, to a pair of time series, between the climatic series and the mortality, according to sex has been investigated. This coherence was determined to characterize these cycles, as the estimated coherence provides the degree of linear association between two series in different bands of frequencies. Using this procedure it makes possible to justify the presence of the oscillations detected in the mortality time series related to the climate.
To represent the variability of mortality, based in the oscillations identified by the spectral analysis, a statistical model of prediction was also applied. The model was applied to the predictors for the months that follows the one with has the number of incidences of deaths caused by respiratory and cardiovascular diseases. The model used is based on Wold's decomposition theorem, following Priestley (1981), and uses the techniques of spectral analysis of the series, and the non-linear and linear regression to obtain each predictor starting from the Fourier series.

3. RESULS AND DISCUSSION

3.1. Empirical Orthogonal Function.

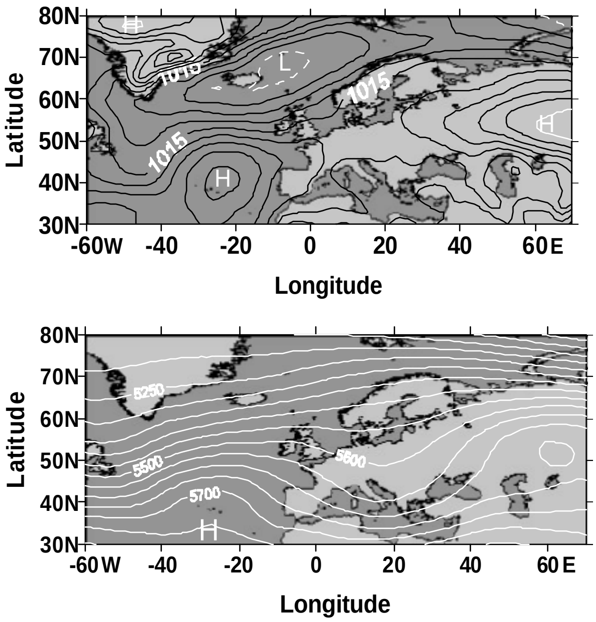

Fig. 1. Synoptic representation of the air mass of type 2, during April for surface and 500 hPa geopotential height.

The April Ats, performing the EOF and applying EOF retention criteria resulted in four identifiers, which accounts for 74% of the original meteorological data. Based on the magnitude of loading components, the physical interpretations of the EOFs were made. Clustering of the four EOF scores resulted in the identification of five Ats. The first EOF represents the thermodynamic variables of temperature and humidity, accounting for a total of 26% of the explained variance. The second EOF explains 25% of the total variance, representing the zonal windiness component and the saturation deficit. The third OEF explains 13% and represents the pressure and the wind direction.

The fourth EOF explains 10% of the total variance and represents the meridional wind component. It is shown in the Fig. 1 (a-b), the synoptic conditions representing the Type AT2 surface and 500 hPa geopotential air mass fields, representing the year on which the total number of admissions, with circulatory system disease was highest, as seen in the Fig. 2 (a-f).
In the surface map, the anticyclone of the Azores is centered just over the Azores and the thermal depression on the southern of main land. In this condition, the intensity of the surface anticyclone is lower and the “depression valley” to the 500hPa is more meridional direction, and therefore displaced toward the Mediterranean area, which coincides with the one fused with the bend of the circumpolar vortex.
The moderately low NW wind sped influence is seen on, high pressure with small oscillations, high temperature and saturation deficit which as a consequence presents highest oscillations in the extreme values of the cloud cover, and in moderately high wind speed.
The inter-annual variability of air mass frequency is presented in Table 1. The table highlights the relative importance of AT4, as shown with relatively high values in April of almost every year, except in 1994, when type AT3 doesn't exist, but it has the April month with greatest number of days with type AT2. It is worth to note, also, that April of 1991 has the AT3 type with the mass of air with more frequency.

Table 1: Percentage of the five-air mass type (AT) occurrence during April

April	AT				
	1	2	3	4	5
1990	7	10	13	63	7
1991	20	30	37	10	3
1992	4	11	32	36	18
1993	6	13	30	40	11
1994	13	40	37	0	10

3.2. Spectral Analysis

There are some mortality series which show a very strong stochastic component; such as the case of the vascular brain diseases of M and the climatic series of the minimum temperature, since they present a very significant variance in the AR(2). For these diseases, the auto-regressive model AR(2) was very significant, since the coefficient of correlation increased (between model and the data) to 90%, which is a very high value comparing to the one obtained only with the deterministic part. The same results are not observed in the results for the opposite sex (F) case, as far as these diseases are concerned. The largest variation explained is found to be between 2 and4 months, in almost all analyzed series.

The clinic behavior is quite different when considering men and women. The mortality caused by myocardial infarction in M presents the highest explained variance (26.3%) of the spectrum, which corresponds to oscillations between 2 and 4 months, while in the F the highest explained variance (29.3%) varies from 4.1 to 7 months.
The differences are also significant when the mortality caused by vascular brain diseases are analyzed, because in the case of M presents higher explained variance (35.7 %) in the peak around 10 to 13 months. (This peak is rather significant in the temperatures and wind speeds), while in the F case the highest explained variance (42%) has the peak between 2 to 4 months.

3.3. Analysis of coherence (SQ)

A significant coherence, over 0.97 in the peaks of <u>12 months,</u> was obtained between the minimum temperatures and the mortality caused by the following diseases: vascular brain (M) and total circulatory (M/F). This significant coherence was also found between wind speed and the mortality due to myocardial infarct (F). A significant coherence, of 0.80, was also obtained, with in the peaks of <u>12 months,</u> between the relative humidity and the mortality caused by the following diseases: vascular brain (M/F) and total circulatory (M).
The SQ of more than 0.80 in the peak of <u>6 months</u> was present between the maximum temperature and the mortality caused by myocardial infarct (M/F). A similar result was also present between wind speed and the mortality caused by myocardial infarct (M/F), BEA (F) and the total respiratory (M).
In the peak of 3 months the SQ decreased a little bit more, though still being rather significant. The SQ over 0.80, in the peak of 3 months, was found between the minimum temperature and the mortality due to: vascular brain diseases (M/F), total circulatory (M/F); and between the maximum temperature and mortality due to vascular brain (M), BEA (M); and between wind speed and mortality due to the total circulatory (M).
Amongst the climatic series that showed more significant SQ with mortality series of M and F, the minimum temperature stands out.
There are more significant SQ for M than for F in all diseases studied, except in the myocardial infarct, where the number of significant SQ for women (3) is superior to the number of significant SQ for men (2).
From these notes it is concluded, once again, a factual answer that the series of male and female mortality due to the climatic elements is really quite distinct.

3.4. Statistical model of forecasting

The Fig.2 (a - f) show the estimated and observed series of all diseases with correlation coefficient of 0.99 and 0.77.

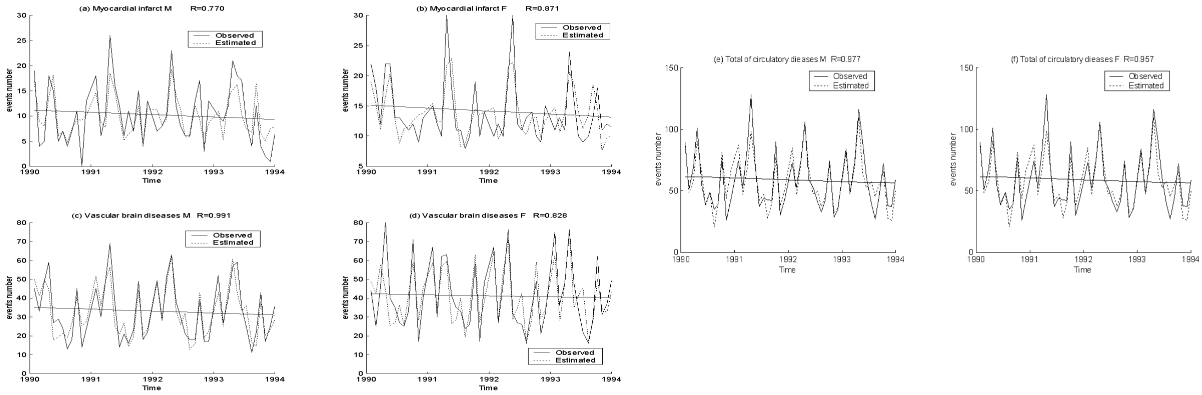

Fig. 2 (a - f) Time series of male and female mortality, observed (dashed line) and estimated (solid line) and respective line of tendency of the observed series

4. CONCLUSIONS

The prevailing meteorological conditions during the period of the highest illness number of admissions presented the as follow: moderately low wind speed in NW direction, a high pressure with small oscillations, high temperature and saturation deficit, and very high oscillations of extreme values of cloud covers with a moderately high wind speed. The AT2 type was the associate climate.

The rate of the mortality distribution presented a maximum seasonal occurrence during Winter, proceeded by the Autumn and Spring and with a minimum during Summer. The April was the month with the largest incidence in the hospital.

The periodicity of the mortality distribution occurrence was confirmed with spectral analysis; that presented oscillations of 3, 6 and 12 months. This periodicity was also confirmed by the high-explained variance values obtained in these peaks (of 3, 6 and 12 months). All diseases showed peaks of 3 months, more distinctly, however, for men than women.

The results showed that there is a noticeable relationship between the climatic elements variation and the mortality. All diseases that caused mortality can be considered as meteorotropic, since they depend on the season according with certain climatic elements.

The existence of a strong coherence (SQ) was shown to be present between the climatic variables and the mortality, especially during the occurrence of minimum temperature periods, with peaks of 3 and 12 months.

It has been conclude, also, that is possible to apply a statistical model to forecast the occurrence of the mortality for the month that follows the analysis. The model showed that there is a strong correlation and therefore a good adjustment between the observed and the estimated values; in addition to a fact that there is a deterministic part and an auto-regressive one (when it is significant).

When the auto-regressive model is significant, the adjustment between the original data and the estimated ones increases considerably. This was the case of some diseases, in which the statistical forecasting model presented to be improved a lot when the auto-regressive part is significant and shows that these diseases have a (random) strong stochastic behavior.

The model, with refined adjustments, between the observed and the estimated, can be applied and used to forecast a short-term (a month) mortality, allowing a more effective and planning procedures answer to the emergency health services.

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