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P. T. Nastos, A. G. Paliatsos, V. P. Tritakis and A. Bergiannaki

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Environmental Discomfort and Geomagnetic Field Influence on Psychological Mood in Athens, Greece

P.T. Nastos[a] A.G. Paliatsos[b] V.P. Tritakis[c] A. Bergiannaki[d]

[a]Laboratory of Climatology and Atmospheric Environment, Department of Geology and Geoenvironment, University of Athens
[b]Technological and Education Institute of Piraeus
[c]Research Center for Astronomy and Applied Mathematics, Academy of Athens
[d]University Research Institute of Psychiatric Hygiene, University of Athens

Key Words

Psychological symptoms · Discomfort · Geomagnetism · Generalised linear models · Athens

Abstract

A multivariate analysis of 4797 cases of patients who were cured of their psychological symptoms and their notes filed by the psychiatric clinic of the Eginition Hospital in Athens, during the year 1994, has been done. The results of this analysis imply significant contribution of environmental variations, expressed by a discomfort index, in the aggravation of psychological symptoms like depression, sleep disturbances, anxiety, aggressiveness, etc. Moreover, geomagnetic field variations expressed by the international geomagnetic index (DST) manifest significant indications that they contribute to the aggravation of sleep disturbances. A clear seasonal variation, with a maximum around August and a minimum at the end of the year, appears in the environmental index, while a double oscillation with a period of about six months is obvious in the geomagnetic index. The same more or less seasonal variation was mirrored in most of the psychological symptoms we analysed in the present study.

Introduction

The influence of environmental conditions on public health was thoroughly investigated by the ancient physicians, whose observations are summarised in the works of Hippocrates. In one of these texts entitled "On the Atmosphere, Water, and Space" we learn the importance of the orientation of a town in relation to the predominant wind direction. Wind direction from the South was identified with unwholesome conditions. Although the idea of an environmental influence on public health was always widespread, quantitative studies on this effect have always come to very poor conclusions. To make research on the subject easier and more comprehensive a lot of bio-climatological indices have been proposed. As early as 1938, Buttner [1] recognised that in order to assess the thermal influence of the environment on the human body, the integrated effects of all the thermal parameters had to be taken into account. He postulated: "If one wants to assess the influence of climate on the human organism in the wider sense, it is necessary to evaluate the effects not only of a single parameter but of all thermal components. This leads us to the necessity of modelling the human heat balance." Since then a lot of thermal indices have been used. The best known of them

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P.T. Nastos
Assistant Professor, Laboratory of Climatology and Atmospheric Environment, University of Athens, Panepistimiopolis GR 157 84, Athens, Greece
Tel./Fax +30 210 7274191, E-mail nastos@geol.uoa.gr

are: Lee's index [2], which is a function of air temperature, humidity and wind speed; the index of Cena Gregorczuck and Wojcik [3], best known as cooling power and expressed by a function of air temperature and wind speed; the empirical index of Lally and Watson [4], labelled "humiture" and renamed "humidex", which is a function of air temperature and vapour pressure; Thom's index [5], labelled as a discomfort index, DI, which is a function of dry and wet bulb temperatures; Kawamura's index [6], which is based on a function of air and dew point temperatures; the effective temperature index (ET), which combines the mean monthly values of air temperature and humidity. Global charts of the ET index have been created and processed by Gregorczuck and Cena [7], for the period January to July.

In the last 15 years, several studies concerning the influence of environmental factors on humans in Greece have been published [8–15]. Theoretical or empirical formulae have attempted to compare the rate of heat loss to surroundings with the rate of heat production by work and metabolism. Recent empirical relations, based on relative comfort expressed by human subjects under differing atmospheric combinations, have attempted to indicate the temperature at which air at some standard humidity, air motion and radiation load would be equally uncomfortable or comfortable [16–18]. New technologies and models applied to animals have attempted to reveal relations among hygienic characteristics and environmental parameters, like geomagnetic activity [16]. However, epidemiological studies lead to conflicting and inconsistent results. In particular, some of these studies suggested a seasonal variation in the incidence or worsening of specific psychological symptoms, which seemed to relate to various environmental conditions [19–23], while others did not observe any significant associations [24,25]. Although some interesting relationships between psychological symptoms and environmental parameters have come out of these studies, most of them suffer from lack of a long and significant data series.

The present study has tried to evaluate the association of both the index of geomagnetic activity and the environmental (discomfort) index with several psychological symptoms in a very large and homogenous sample of patients, overcoming in this way various statistical difficulties, which most of these studies always encounter.

Data and Methods

A large and homogeneous sample of 4797 outpatients, obtained from the daily records of the psychiatric clinic of the Eginition Hospital in Athens during the year 1994, have been processed. Two thousand five hundred and twenty one of them (53% of the cases) were male (37.6 ± 14.7 years old) while 2276 cases (47%) were female (40.6 ± 16.4 years old). At first glance it is clear that the females were significantly older than the males ($p < 0.001$). The monthly distribution of the psychological symptoms investigated during the year 1994 is tabulated in Table 1. Anxiety–panic (1675 cases, 35%), depressive mood (1377 cases, 29%) and sleep disturbance (1400 cases, 29%) share the majority of the symptom cases and percentages.

The main object of this analysis is to reveal possible relationships between various psychological symptoms mentioned above and specific environmental parameters

Table 1. Monthly distribution of the psychological symptoms investigated during 1994

	Aggressive mood	Self destructive mood	Sleep disturbance	Anxiety–panic	Depressive mood
January	20	12	113	120	103
February	17	9	93	124	93
March	24	16	106	138	107
April	25	14	132	169	123
May	16	11	101	125	102
June	27	10	118	138	124
July	32	18	124	169	109
August	38	13	160	105	117
September	18	13	146	177	160
October	23	6	107	152	138
November	29	6	93	126	108
December	17	10	107	132	93
Total	286	138	1400	1675	1377

like discomfort index and geomagnetic index. For estimating discomfort index (DI) in degrees Celsius the following equation by Giles et al. [26] has been applied:

$$DI = T_a - 0.55\,(1 - 0.01\,RH\%)\,(T_a - 14.5)$$

where T_a is the daily value of the mean air temperature in degrees Celsius and RH% is the corresponding daily value of the relative humidity. Regarding the population of the greater Athens area, it is accepted that there is no discomfort when $DI < 21°C$, less than 50% of the total population feels discomfort when $21°C \leq DI < 24°C$ and more than 50% of the total population feels discomfort when $24°C \leq DI < 27°C$. Most of the population suffers discomfort when $27°C \leq DI < 29°C$, while the discomfort is considerable and potentially dangerous when $29°C \leq DI < 32°C$. In the last case a state of medical emergency must be announced. The data of daily values of mean air temperature and relative humidity for the computation of DI daily values for the year 1994, obtained from the records of the Institute of Environmental and Sustainable Development Research (IESDR) of the National Observatory of Athens (NOA) (longitude: 23° 43′ E, latitude: 37° 58′ N, altitude: 107 m amsl.). On the other hand, geomagnetic conditions could be well described by the DST index. This is a very objective daily geomagnetic index, which monitors and records equatorial ring current variations accurately.

The daily values of the DST index are collected as averages of hourly measurements by a number of observatories located in the equatorial zone of the earth. Hourly values of the DST index for each observatory j are derived from the equation:

$$DST_j = H_{obs,j} - Sq_j(t) - H_{o,j}(t)$$

where $H_{obs,j}$ is the hourly average of the horizontal field recorded in a certain observatory, $Sq_j(t)$ is a statistical factor computed at each station for each month by using the five local days that have a maximum overlap against the five international quietest days and $H_{o,j}(t)$ the annual means of the geomagnetic field for the five international quietest days of the months [27,28].

The daily values of DI vary from 6.96 to 27.08, while the daily values of DST index vary from −104 to 18 (Figure 1). The annual mean value of the DI was equal to 18.01 (±5.07), while for the DST index it was found equal to −21.28 (±18.74). The observed daily frequencies of the DI and DST were not normally distributed (DI: Kolmogorov–Smirnov $d = 0.112$, significance level $p < 0.01$, DST: Kolmogorov–Smirnov $d = 0.108$, significance level $p < 0.01$). As we can see from Figure 1, a bell-shaped curve best describes the intra-annual distribution of daily values of DI with a peak observed during the summer time, especially between July and August. On the other hand, the DST index varies during the year with minima in the transitional seasons, spring and autumn, and maxima in the basic seasons, summer and winter.

In our effort to increase significance, we applied the generalised linear models (GLM) described by McGullagh and Nelder [29]. According to their theory the link function that relates the linear predictor η to the $E(Y) = \mu$ in classical linear models is the identical link, $\mu = \eta$. However, when the outcome (response variable) deals with counts (i.e. in our case total number of outpatients per day), then the data follow a Poisson type of distribution. In this case we get $\mu > 0$, so that the identity link is not attractive because $\eta < 0$ while $\mu > 0$. Thus, models for counts based on independence in cross-classified data lead, naturally, to multiplicative effects and the appropriate link is the log-function [29]:

$$\eta = \ln(\mu) \Rightarrow \mu = e^{h}$$

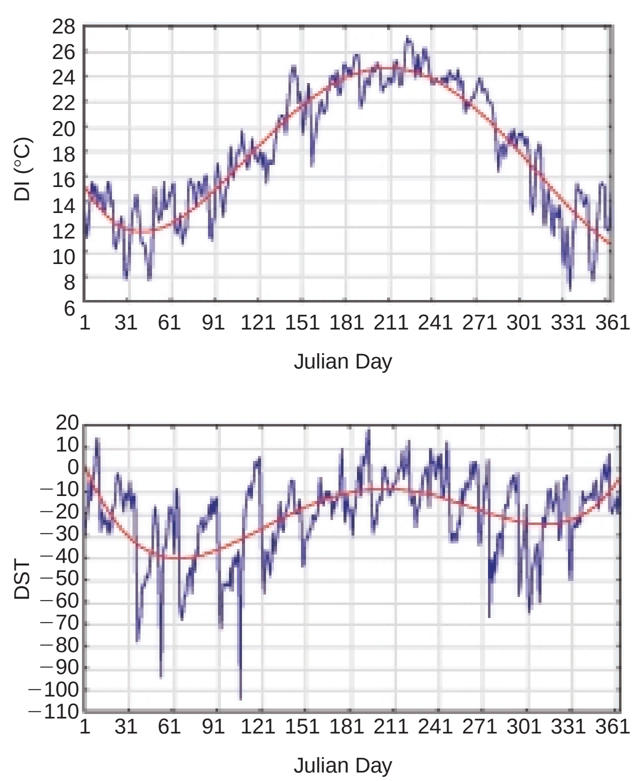

Fig. 1. Annual variation of DI and DST daily values, along with a polynomial smoothing.

In the fitting procedure for the models we used, a dependent variable was the daily number of outpatients with each of the investigated symptoms that were admitted to the psychiatric clinic of the Eginition Hospital in Athens, while as independent co-variates we used the aforementioned indices. Models' goodness-of-fit was evaluated through deviance residuals [29].

Results and Discussion

In order to visualise the possible influence of the DI and DST indices with each one of the psychological symptoms, detailed diagrams were drawn and are presented in Figure 2. The total number of each symptom per 10-day interval was calculated and the time series along with a polynomial

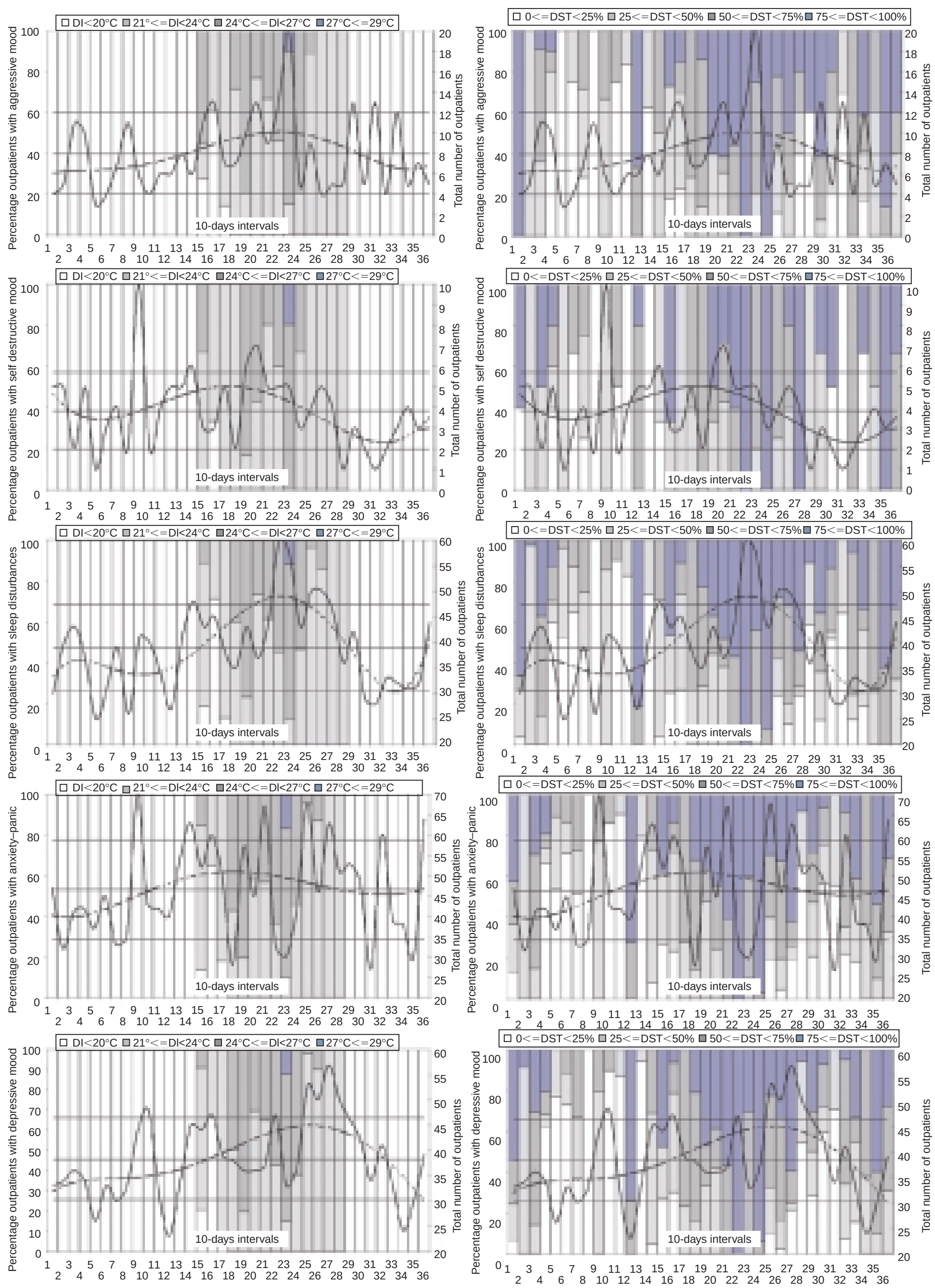

Fig. 2. Relative frequency (%) of each psychological symptom per 10-day interval as a function of DI (left panel) and DST (right panel) along with the variation of the total number of outpatients per 10-day interval (solid line) and polynomial fitting (dash line).

smoothing during the period examined are depicted. In addition, the relative frequencies of each symptom per 10-day interval as a function of DI classes (left panel) and DST percentiles (right panel) are also illustrated within the same diagrams. Three reference lines concerning the mean, the mean + SD and the mean − SD are also depicted, in order for the deviations to be seen more clearly.

The 10-day interval analysis highlighted that high values in the admissions of patients with aggressive mood (exceeding the mean + SD) were associated with the upper classes of the DI index (DI > 24°C) and this occurred mainly during summer time. Also, high values of the DI seemed to influence the total number of admissions of patients with a self destructive mood, but this

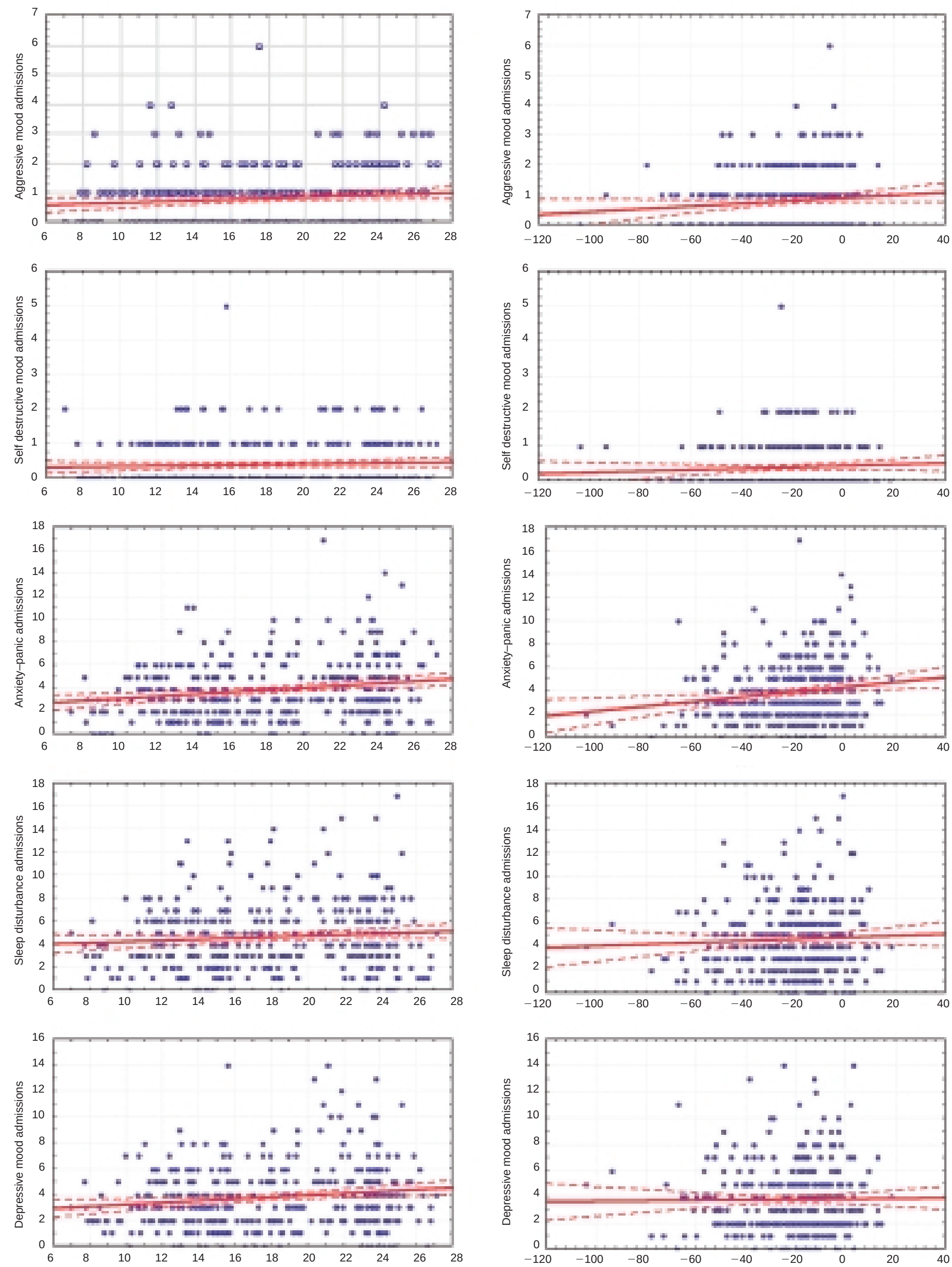

Fig. 3. Relationships between each psychological symptom admissions and DI (left panel) and the DST (right panel).

relationship was rather weaker than the previous one mentioned. A strong relationship between the total number of outpatients with sleep disturbances and high values of the DI was suggested, revealing that sensitivity to weather has an effect on sleep disturbance, a finding in agreement with that of Faust and Hole [30] and Mackensen et al. [31]. The main peak exceeded considerably the mean + SD level and this happened during the two heat waves recorded in Athens, in 1994. The total number of outpatients with anxiety–panic per 10-day interval appeared to have great variability around the mean, while remarkable peaks appeared during the cold period of the year (October–March). This is in agreement with the findings of a recent study carried out in Japan, where higher prevalence of panic attacks and panic disorders were found to take place in the colder areas of Japan [32]. The peaks of depressive mood symptoms seem to be shifting towards the beginning of autumn and coincide with the end of summer holidays. Concerning the DST index and its influence on the total number of outpatients with psychological symptoms, an association between a high incidence of sleep disturbance and the upper percentile of DST ($75 \leq DST < 100\%$) was evident.

Figure 3 manifests the relationships between each psychological symptom in the admissions and DI (left panel) and DST (right panel). The bivariate correlations between the number of admissions and each one of the indices are relatively low. This is because the majority of the days (about 50%) were without admissions, especially with regard to those with aggressive and self destructive symptoms. This meant that the frequency distribution of the data deviated from the normal as mentioned before. A Poisson distribution fitted the data better. In order to assess increasing significance of qualitative results, the application of GLM models was carried out. Table 2 illustrates the results extracted by the application of GLM models on the daily values of the discomfort index, geomagnetic index DST and psychological symptoms. Interpreting the findings according to the GLM statistical analysis, we can note that a 10-unit increase in the discomfort index is associated with an increase in aggressive mood symptoms by 13% (not statistically significant, $p = 0.297$), a decrease in self destructive mood by 0.2% (not statistically significant, $p = 0.991$), an increase in sleep disturbance by 27% (statistically significant, $p < 0.001$), an increase in anxiety-panic by 15% (statistically significant, $p = 0.004$), and an increase in depressive mood by 23% (statistically significant, $p < 0.001$). Work in Israel [33] found that increased environmental temperature may be a risk factor for evolution of a major depressive episode in patients with bipolar disorder with psychiatric co-morbidity. As far as the DST index is concerned, a ten-unit increase in this geomagnetic index links to an increase in sleep disturbance episodes by 6% (statistically significant, $p < 0.001$).

If we apply the previous analysis, using as an outcome

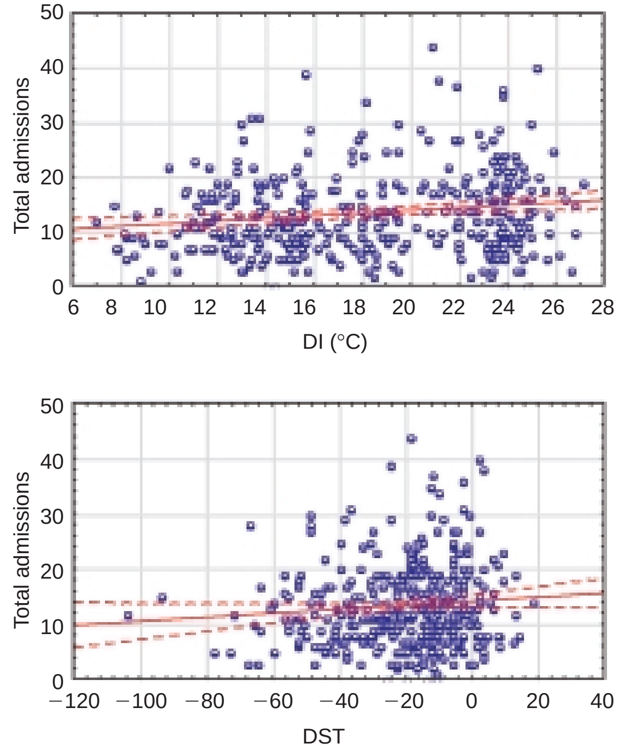

Fig. 4. Relationships between total psychological symptoms admissions and DI (left panel) and the DST (right panel).

Table 2. Results from the generalised linear models for the evaluation of the effect of discomfort and DST-index on the development of several psychological symptoms

	β-coefficient ± SE	Significance level
Discomfort index (DI)		
Aggressive mood	0.012 ± 0.011	0.297
Self-destructive mood	−0.0002 ± 0.017	0.991
Sleep disturbance	0.024 ± 0.005	<0.001
Anxiety–panic	0.014 ± 0.005	0.004
Depressive mood	0.021 ± 0.006	<0.001
DST-index		
Aggressive mood	0.005 ± 0.003	0.128
Self-destructive mood	0.002 ± 0.004	0.706
Sleep disturbance	0.006 ± 0.002	<0.001
Anxiety–panic	0.002 ± 0.001	0.075
Depressive mood	−0.001 ± 0.001	0.373

the total number of outpatients who entered the psychiatric clinic for any of the symptoms noted previously, we find a greater statistical association (Figure 4). In particular, ten-unit increase in the discomfort index links to an increase in any one of the psychological symptoms by 20% (95% CI 14–27%, $p < 0.001$). In addition, moderate to intense discomfort ($DI > 24$) seems to double the risk (odds ratio = 1.76, 95% CI $0.771 - 4.020$, $p = 0.179$) when observing the daily number of outpatients in the upper quartile (i.e. more than 18 cases with psychological symptoms per day) compared to the lower quartile (i.e. less than eight cases with psychological symptoms per day). It is necessary to mention that, to eliminate the information bias, we used data from the patients' medical records.

Conclusions

The findings from the present study suggest that an association between the DI and the daily number of outpatients' visits to the psychiatric emergency unit seems to exist. More specifically, sleep disturbances and depressive mood are influenced more by environmental discomfort as shown by the 10-day interval analysis and the application of GLM models with Poisson distribution on the data sets examined. On the other hand, borderline associations were observed between the geomagnetic index and the prevalence of several psychological symptoms. We remark that a ten-unit increase in the DST is associated with an increase by 6% in sleep disturbance (statistically significant, $p = < 0.001$). Prospective studies are necessary to establish more about the influence of the environment on human hygiene, given that the researchers generally agree that most of the impacts of climate change on human health are likely to be adverse. Should global warming increase the frequency and/or severity of extreme weather events such as heat waves, droughts, floods, landslides and tropical cyclones, it is likely that more deaths, injuries, infectious disease cases and psychological disorders could result [34,35].

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