Possible Hazards to Human Health Caused by Changing in Urban Climate

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Abstract-**The emission of greenhouse gases produced by the HVAC plants, transport networks and other anthropic activities in urban areas, produces a deep impact on the local atmospheric conditions, as the urban heat island (UHI), heat waves and so on. The alteration of climate condition (temperature, humidity, etc.) makes the urban environment out of the homeostatic plateaux of human species. The main bioclimatic indexes may be used in urban climate studies to describe the level of thermal sensation that people feels because of climatic conditions. These indexes provide a meaningful and realistic indicator to readily discover possible physiological and psychological damages that people could suffer for the effects of altered bioclimatic conditions. To the aim to prevent harmful health effects of heat-waves, the authors have developed a model to predict the weather for the next day thanks to an Artificial Neural Network (ANN) technique. In this way the researchers have used the forecasted meteorological data to calculate the bioclimatic indexes. The values of the bioclimatic indexes calculated using the forecasted meteorological data by ANN have been validated by comparing with the bioclimatic indexes values calculated using the data (temperature, relative humidity and wind velocity) recorded, in the same interval of time, from the meteorological stations. The authors have verified that the proposed methodology have a good level of accuracy. The proposed methodology could constitute an useful tool to predict the health risks related to heat wave and usable as heat health alert system to activate social and health care networks.**

Keywords-Human Health; Urban Climate; Bioclimatic Index

I. INTRODUCTION

Scientific consensus exists in that climate change is anthropogenically forced, with effects shown on the ecological system and human health already [1]. Greenhouse gas is widely assumed to be the cause of global warming and accelerated climate-change. Climate change is expected to be increasing global average temperatures, as well as the number and intensity of heat waves, more frequent natural disasters such as storms, floods, droughts, and wildfires, resulting in injury, disease, and mortality. The projected temperature increase for Europe by the end of the twenty first century is 2.3–6.0° C [1]

Changes in average climate, seasonal patterns, and an increase in the number and intensity of extreme events will also affect air quality, particularly in ground-level ozone, and allergenic pollens adding to the burden of chronic illnesses.

Cities are the major contributors to global warming of the troposphere by simultaneously emitting heat and thermally activated climate changing CO_2 gases in an unholy alliance. Although CO_2 is generally well-mixed in the atmosphere, data indicate that its mixing ratios are higher in urban than in background air, resulting in urban CO2 domes [2-4]. Despite our knowledge of these domes for over a decade, no study has contemplated their effects on local temperature, water vapour or the resulting feedback to air pollution and health.

Urban areas have a profound impact on the local atmospheric conditions. The materials in buildings and the urban infrastructure absorb solar radiation and anthropogenic heat generated by urban lifestyles and energy use, and in conjunction with the loss of natural thermal sink (green areas especially) cause the temperature of urban air domes to range up to 10° C warmer than the surrounding countryside [5] . UHI intensity is often determined using the difference between the peak urban-rural temperatures from individual observing locations [6, 7, 8]. In general, the UHI is mostly noticeable at night and under synoptic high pressure systems with calm conditions and clear skies [8, 9, 10]

The architectural composition of city unavoidably involves urban canyons which thermally exaggerate the absorption of heat. In particular, high rise and high thermal mass canyons magnify the impact of the built environment on urban climate by trapping heat [11] and reducing long wave heat loss as well as cooling potential [12]. This heat absorbed by the greenhouse gases present in urban atmosphere influence a wide range of ecological parameters. Precipitation intensity, thunderstorm, hail, and violent winds are all exacerbated [13]. Humidity, cloud cover, fog and snow are also impacted [14]. Moreover, recent research discovered that during that heat wave parched forests and grassland emitted huge quantities of carbon dioxide [15]. Furthermore, it is not widely appreciated that air pollution in cities is exacerbated by both heat and sunlight, while the toxicity of the photochemical ozone is intensified: for example, the VOCs revving up and having more potent affects than on average winter’s day [16].

Another UHI human factor impacts is thermal comfort. People are thermodynamic beings, acclimatized to particular conditions and sensitive to the slightest change in temperature, by which our moods, comfort, performance, and health affected in turn. Both indoors and in city streets and urban squares comfort make up a large component of our livability and habitability experiences, and put simply our ability to enjoy the environment [14].

The urban climate is possibly the most important factor to be considered in any suitable and habitable urban design process. Generally, there are at least three salient eco-logical design aspects which could moderate UHI conditions: naturally cooled buildings, greening of streets and urban squares, and the urban geometry of pedestrian priorization – in particular, organic street grids.

Climate changes in the last 50 years have been well documented, but the influence on population health has not been sufficiently examined so far. In recent years, the effects of heat waves had devastating impacts in Chicago in 1995 [17, 18] and Paris in 2003 where deaths due to heat-related illnesses were equally devastating [19]. Climate projections suggest that these events will become more frequent, more intense and longer lasting in the remainder of the 21st century [6] and, as a result, many cities have implemented heat watch-warning technologies to mitigate the impacts of heat waves and protect the populations of the associated urban areas [20,21].

Heat waves are more human destructive than other urban calamities including floods and hurricane, particularly to the more vulnerable segments of populations: the elderly and very young. The IPCC suggests starting research in this field by analyzing the association of the mortality or morbidity incidences with short-term changes in weather and climate, and using short-term temperature fluctuations as one of the main markers.

Numerous epidemiological studies show worldwide the health and social impact of extreme thermal conditions such as heat waves [22]. The most direct effect of whether on human mortality in mid-latitudes are observed during and after summer heat waves that lead to significant increase and intra-seasonal shifts in total mortality [23]; so heat waves can be not only extremely uncomfortable, but even deadly.

This relation seems to be stronger than those between mortality and other environmental factors, such as atmospheric pollution.

The risk of premature death due to temperature increases associated with global warming is six times higher for Europeans who are already suffering from respiratory problems, according to the European Respiratory Society (ERS) [23]: for instance, a one degree Celsius increase in temperature produces a 1-3% increase in deaths in the general population, but this same temperature increase results in a 6% increase in deaths among people with respiratory conditions. During the hot summer 2003, in the WHO European Region about 55,000 extra deaths attributable to heat occurred in Europe, and from these about 35,000 alone in August 2003 [22]. During summer season or in very hot periods anyway, the human organism makes use of perspiration (endothermal phenomenon) to maintain its temperature within proper physiological limits. A high humidity level in the surrounding environment may obstruct this process limiting the evaporation, so the human body can't eliminate the excessive heat (compared to its own physiological limits) causing overheating that can be very dangerous.

Heat exhaustion occurs when the body loses fluid and salt through faster perspiration than they can be replaced which results in dizziness.

People not used to exercising in hot weather may experience a quick drop in blood pressure that can lead to fainting. In some cases, extreme heat can cause body temperature to rise to 105 degrees or higher, causing a heat stroke, with confusion and unconsciousness.

When heat and humidity combined with slow evaporation of sweat from the body, outdoor exercise becomes dangerous for not only elderly and the ill, but also for young people in good shape, who do not recognize the dangers of exercising in hot weather, especially hot humid weather.

Dangers of heat include:

Heat cramps: exercising in hot weather can lead to muscle cramps, especially in the legs, because of brief imbalances in body salts. Cramps become less frequent as a person becomes used to the heat.

Heat syncope or fainting: anyone not used to exercising in the heat can experience a quick drop in blood pressure that can lead to fainting. For heat cramps, the cure is to take it easy.

Heat exhaustion: Losing fluid and salt through perspiration or replacing them in an imbalanced way can lead to dizziness and weakness. Body temperature might rise, but not above 102 degrees. In some cases, victims, especially the elderly, should be hospitalized. Heat exhaustion is more likely after a few days of a heat wave than at just beginning. The best defence is to take it easy and drink a plenty of water. Don't take salt tablets without consulting a physician.

Heatstroke: In some cases, extreme heat can upset the body's thermostat, causing body temperature to rise to 105 degrees or higher. Symptoms are lethargy, confusion, and unconsciousness. Even a suspicion that someone might be suffering from heatstroke requires immediate medical aid. Heatstroke can kill people.

II. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Network can be defined as a connected computational system able to store and utilize knowledge acquired through experiment. The knowledge acquired is stored with the help of values of certain parameters, called weights, which connect the computational units, known as nodes or neurons, whose values are fixed during the training phase.

Every neuron is an entity which has access to several inputs and one output only. It receives the inputs from neighboring neurons, elaborates them and transmits the output to other neurons, appropriately weighting them by means of the connective values. The neuron model currently being most used is reported in Fig. 1, where x_i represents the i^{th} input (the i^{th} component of the vector X), w_i is the relative weight at the i^{th} input (the i^{th} component of the vector W), and $f(W^tX)$ is a function, generally a non-linear one, known as the activation function . The value of the activation function, calculated at the weighted addition of the inputs, thus represents the neuron output. The number of input and output neurons known to be related to the application while the hidden structure is chosen from one time to another and determines the performance of the net.

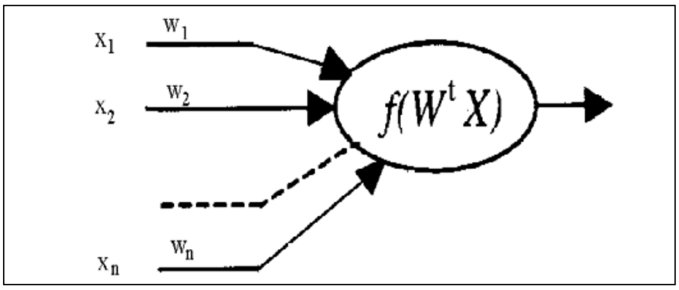

Fig. 1 Neuron Network

There are three different operational phases of the networks. The first is the learning or training phase. During this phase, a set of examples are provided to the network. These data, using different learning algorithm, chosen according to the network structure and type, are used to update the weight values.

The second phase is called the test phase or checking phase and, by using a different data set, serves to verify that at the end of the learning the network is functioning correctly. In this phase, the weights of the net are "frozen" at the previously determined, learning phase, values. Once these two phases are completed, the net can be used for calculating the output in the face of unknown input.

The neural structure applied in the paper is the Multilayer Perceptron (MLP). As shown in Fig. 2, the multilayer perceptron is made up of a layer of input neurons that have the goal of transferring the signal to the next layer, giving it the appropriate weights from a certain number of internal layers, also known as hidden layers, and from a layer of output neurons. The neurons of each layer are all connected by weights with those of the previous and successive layers. The MLP structure is thus characterized by the number of hidden layers and the number of neurons in each layer [24].

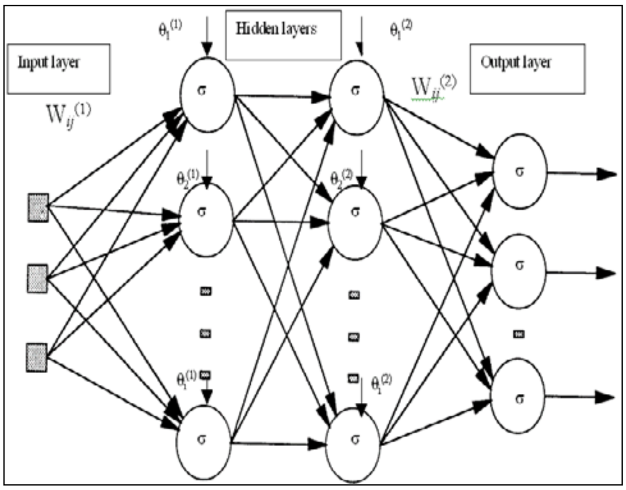

Fig. 2 Multilayer Perceptron diagram with two hidden layers

The Stone-Weierstrass theorem, which offers a rigorous demonstration of the universal interpolation property of a MLP with at least one layer of hidden neurons, provides the theoretical background for the neural network application. In fact, it has been proved that a MLP-type artificial neural network with at least three layers and one sigmoidal activation function for the neurons of the hidden layer is able, to any degree of accuracy that may be required, to interpolate a continuous non-linear function or one with a finite number of discontinuities.

With regard to the learning of a MLP, it takes place by means of an iterative algorithm that updates the values of the network interconnections such that a total square error functional optimizing on a set of input/output data is defined. At this point, the gradient algorithm for back-propagation of the output layer keeps applying error until the first hidden layer simultaneously updating the value of the weights, according to the deepest-descent gradient formula [25].

III. THE BIOCLIMATIC INDEX

For human being it is crucial to keep the body's core temperature at a constant level (37°C) in order to ensure functioning of the inner organs and the brain.

The human thermoregulatory system can be separated into two interacting sub-systems:

- the controlling active system which includes the thermoregulatory responses of shivering thermo genesis, sweat moisture excretion, and peripheral blood flow (cutaneous vasomotion) of not acclimatized subjects,
- the controlled passive system dealing with the physical human body and the heat transfer phenomena occurring in it and at its surface ,

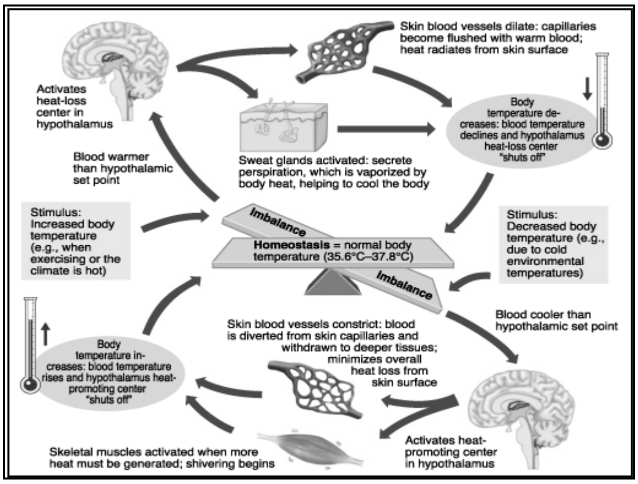

Fig 3. Human physiological and behavioural thermoregulation

(B. Cummings 2001)

The heat exchange between the human body and the thermal environment can be described in the form of the energy balance equation.

$$M - W - \left[Q_H\left(T_a, v\right) + Q\left(T_{mrt}, v\right)\right] - \left[Q_L\left(e_v, v\right) + Q_{sw}\left(e_v, v\right)\right] - Q_{RE}\left(T_a, e_v\right) \pm S_a = 0 \quad (1)$$

The human thermal environment cannot be represented adequately with just a single parameter, so more than 100 simple thermal indices have been developed and most of them are two- parameter indexes.

The bioclimatic indexes most commonly used in urban climate studies, to quantify the discomfort in summer season, are the Humidex, the Discomfort Index (DI) of Thom, the Summer Simmer Index (SSI), the apparent temperature and so on.

The Humidex was created by J.M. Masterton and F.A. Richardson (1979) to quantify and include the degree of risk for the human body in the event of heat and excessive moisture.

$$\text{Humidex} = T + 5/9 * (e^{-10}) \quad (2)$$

e = vapour pressure

= (6.112*10^(7.5*T/(237.7+T))*H/100) (3)

T= air temperature (degrees Celsius) H= humidity (%)

Table I shows the correlation between the values of the Humidex and the correlated human discomfort. The new Summer Simmer Index (SSI) was presented in California in January 2000. It uses the results from physiological models and human trials conducted over a period of more than 75 years by the American Society of Heating and Refrigeration Engineering (ASHRAE) at the University of Kansas.

TABLE I

HUMIDEX AND THE CORRELATED HUMAN DISCOMFORT.

Humidex Range	Degree of Comfort
20-29	comfortable
30-39	some discomfort
40-45	great discomfort; avoid exertion
above 45	dangerous
above 54	heat stroke imminent

The new Summer Simmer Index (SSI) describing the conditions of heat stress during hot weather and his formula is [26]

$$SSI = 1.98? \begin{Bmatrix} \left[T_a - (0.55-0.0055?(H)\right] \\ ?\ (T_a\ ?\ 8) \end{Bmatrix} -56.83 \quad (4)$$

Seven zones have been identified to describe the thermal sensation of the SSI index.

TABLE II

THERMAL SENSATION OF THE SSI INDEX

zone	SSI	Thermal Sensation
1	from 70 to 77	most people are comfortable, but slightly cool
2	from 77 to 83	nearly everyone feels quite comfortable
3	from 83 to 91	most people are comfortable, but slightly warm
4	from 91 to 100	increasing discomfort(warm)
5	from 100 to 112	a caution of sunstroke and heat exhaustion exists for prolonged exposure and activity, along with significant discomfort (extremely warm)
6	from 112 to 125	virtually everyone is uncomfortable, a danger of heatstroke and great discomfort exists (hot)
7	from 125 to 150	there is an extreme danger of heatstroke, especially for the weakened or elderly, and even young children, whosebody metabolism demands cooler effective temperatures than most adults. Maximum discomfort exists at these conditions (extremely hot). Beyond 150, circulatory collapse is imminent for prolonged exposure

Obviously the formulas used to calculate the discomfort indexes produce theoretic average data that may be highly influenced by a lot of human and environmental factors such as: height, weight and sex of the individual, clothes used, presence of shade or wind, carried out activity.

In winter season, it can be used the wind chill or the Winter Scharlau Index.

The Winter Scharlau Index reflects the level of human discomfort felt because of skin exposure to the cold.

The Winter Scharlau index can be expressed by the formula [27]

$$IS=T-Tc \quad (5)$$

$$Tc=(-0.0003\times H^2)+(-0.1497\times H^2)-7.7133 \quad (6)$$

TABLE III

WINTER SCHARLAU INDEX AND THE CORRELATED HUMAN DISCOMFORT

Condition	Winter Scharlau Index	Degree of Comfort
A	$IS \geq 0$	Comfort
B	$-1<IS<0$	Generally unpleasant (chilly)
C	$-3<IS \leq -1$	Unpleasant (cold)
D	$IS \leq -3$	Very unpleasant (very cold)

IV. METHODOLOGY

The general form of a time-discrete NARMAX (Non-Linear Auto-Regressive Moving Average with Exogenous Input) model is as follows:

$$y(k)=F\left[y(k-1),...,y\left(k-n_y\right),u(k-1),....u\left(k-n_u\right)\right] \quad (7)$$

U(k) and y(k) are respectively the input and output of the system. In the study case y(k) and u(k) represent samples of the considered variables that are: air temperature, in the following indicated as(T), solar radiation (RS), relative humidity (UR), wind speed (VV) and wind direction (DV).

Daily data, from years 2003 to 2006, recorded by meteorological station of the Pergusa Lake (Enna, Italia) have been used to train and test neural networks. Training phase has been performed using years from 2003 to 2005, while 2006 has been used for the test phase. In particular the test phase

acquired data have been filtered, adjusting sensor errors and offset and interpolated in case of missing samples.

As previously introduced, the unknown function F has been identified by means of artificial neural networks, as described in the following models. In particular, a Multi-Layer Perceptron (MLP) with 20 hidden neurons has been adopted.

Several models with a different number of regressions for each variable have been tested. An extensive trial-and-error phase has led to the models characterized by the following structures:

$$T_a(k)=F\begin{bmatrix} T_a(k-2), S(k-2), H(k-2), D(k-2), VV(k-2), \\ T_a(k-1), S(k-1), H(k-1), D(k-1), V(k-1) \end{bmatrix} \quad (8)$$

$$H(k)=F\begin{bmatrix} H(k-2), T_A(k-2), ?S(k-2), D(k-2), V(k-2), \\ H(k-1), T_A(k-1), ?S(k-1), D(k-1), V(k-1) \end{bmatrix} \quad (9)$$

$$V(k)=F\begin{bmatrix} V(k-2), T_a(k-2), S(k-2), H(k-2), D(k-2), \\ V(k-1), T_a(k-1), S(k-1), H(k-1), D(k-1) \end{bmatrix} \quad (10)$$

V. RESULTS

The following figures show the comparison of the NN-Estimated bioclimatic indexes with the coincident bioclimatic indexes values obtained from air temperature, relative humidity, and velocity observations recorded by the meteorological stations installed at Pergusa Lake (Enna).

It has been noted that for more or less in the 25% of cases, (23 days) have been verified extremely dangerous conditions for elderly and persons with pre-existing cardiovascular and respiratory diseases. From the result of analysis, we can see that there wasn't substantial difference between the two different bioclimatic indexes considered. The results of winter index have showed only the reliability of the proposed methodology.

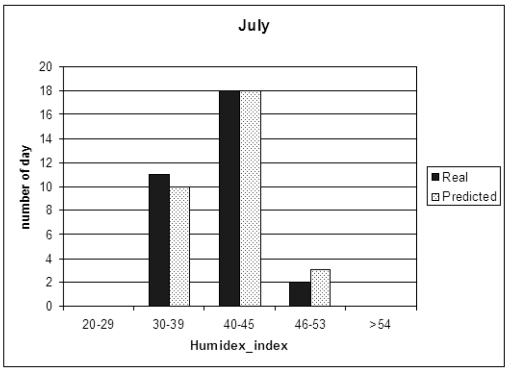

Fig. 4 Values of Humidex Index (July 2006)

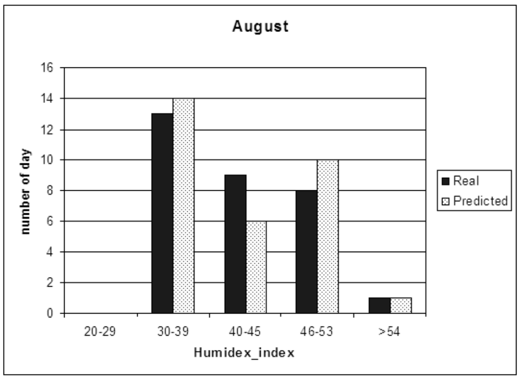

Fig. 5 Values of Humidex Index (August 2006)

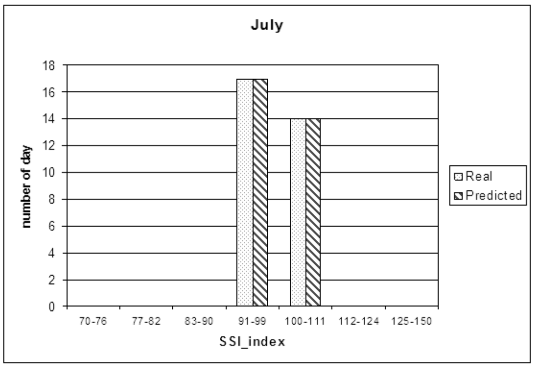

Fig. 6 Values of SSI (July 2006)

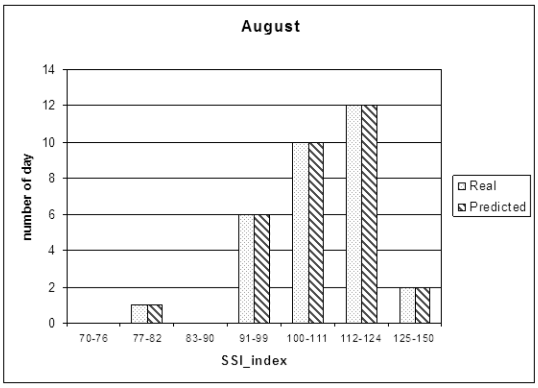

Fig. 7 Values of SSI (August 2006)

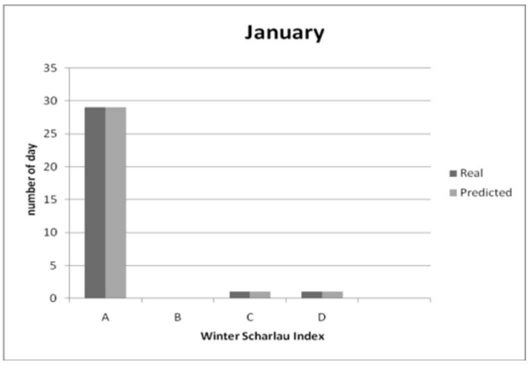

Fig. 8 Value of Winter Scharlau Index (January 2006)

From the result of analysis for the winter season, we can see that there wasn't a substanzial difference of the two index. There was a perfect match between the real value and predicted in the case of the Winter Scharlau.

VI. CONCLUSIONS

This study illustrates a methodology useful to predict the daily value of bioclimatic indexes (Humidex and the SSI) utilising meteorological data.

The authors have used the ANN technique to forecast meteorological parameters (wind velocity, temperature, humidity and solar radiation), utilising data recorded by weather stations during previous days.

The work reports the results obtained for the Urban Area of Enna (Italy). The obtained results demonstrate a good correlation between predicted values of bioclimatic indexes, calculated by means the ANN, and real values of bioclimatic indexes.

The bioclimatic index provides a meaningful and realistic temperature equivalent that can not only be used as an indication as how hot it feels, but also as a readily identifiable warning for individuals subject to the physiological dangers of heat exposure.

The elderly and persons with pre-existing cardiovascular and respiratory diseases are mostly at risk of death from ambient heat exposure; these risks can be prevented if we can provide warning systems and information for respiratory patients.

The proposed methodology, to predict the value of the bioclimatic indexes, could be used as a public awareness for elderly and persons with pre-existing cardiovascular and respiratory diseases that are most at risk of death from ambient heat exposure.

VII. NOMENCLATURE

M = Metabolic rate (activity)

W = Mechanical power;

S_a = Storage (change in heat content of the body)

Q_H = Turbulent flux of sensible heat;

Q = Radiation budget;

Q_L = Turbulent flux of latent heat (diffusion water vapour) ;

Q_{SW} = Turbulent flux of latent heat (sweat evaporation);

Q_{Re} = Respiratory heat flux (sensible and latent)

T = Air temperature;

T_{mrt} = Mean temperature

v = Air speed relative to the body;

e = Partial vapor pressure

H = Humidity;

Tc= Critical temperature

S = Solar Radiation

D = wind direction

V= Wind Velocity

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