MethodsX 11 (2023) 102331

Contents lists available at ScienceDirect

MethodsX

journal homepage: www.elsevier.com/locate/methodsx

The meteorological contrast index in the context of climate change and public health ☆

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A R T I C L E I N F O

Method name:
Meteorological Contrast Index (MCI)

Keywords:
Biometeorology
Climate change
Public health
Distress
Synoptic classifications
Epidemics

A B S T R A C T

In the context of climate change, extreme weather events and sudden shifts in weather patterns are becoming increasingly frequent. The atmosphere is considered a source of meteorological and climatic risks for human beings and living organisms. Numerous studies have examined the correlation between meteorological variables and human morbidity and mortality. However, only a few authors have investigated the impact of environmental changes on human health and, to our knowledge, there are no meteorological indices proposing a methodology for assessing changes in atmospheric conditions. Under the hypothesis that meteorological disruptions have an impact on human health, this article proposes a method to calculate a new index, the Meteorological Contrast Index (MCI), based on weather changes. This index takes into account three variables: i) categorization based on the type of atmospheric process, ii) changes in these categories over a specific time period, and iii) the level of stress associated with these changes, considering the severity of the transition from one category to another. If the predictive value of this index is proven for a specific meteorological variable and disease, it could be valuable in defining biometeorological early warning systems for the prevention and management of healthcare resources.

- The Meteorological Contrast Index is the first index that proposes a method to assess changes in atmospheric conditions.
- Atmospheric changes are a significant source of biometeorological distress, which can be quantitatively defined using the Meteorological Contrast Index.
- Certain diseases are sensitive to the weather, and their incidence may increase under specific sequences of weather types.

Specifications table

Subject area:	Earth and Planetary Sciences
More specific subject area:	Climatology, Public Health, Thermal Comfort, Climate Adaptation
Name of your method:	Meteorological Contrast Index (MCI)
Name and reference of original method:	P. F. De Arróyabe Hernáez, Climate, weather and flu diagnoses incidence in the region of Santander (Northern Spain) during the 1999-2000 epidemic diffusion period, Aerobiologia, 20 (2004) 223–228. 10.1007/s10453-004-1186-z
Resource availability:	N.A.

☆ **Related research article** P. F. De Arróyabe Hernáez, Climate, weather and flu diagnoses incidence in the region of Santander (Northern Spain) during the 1999-2000 epidemic diffusion period, Aerobiologia, 20 (2004) 223–228. 10.1007/s10453-004-1186-z.

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https://doi.org/10.1016/j.mex.2023.102331
Available online 23 August 2023

Introduction

Atmospheric variables interact with living organisms and human beings in multiple ways. Distribution of life in the world responds to several factors, among them climatic variables (such as sunlight, rainfall or temperature) that play a key role. Moreover, in a specific geographic location each individual has a physiological adaptation to the environment that will determine their biometeorological profile, which means how vulnerable they are to changes in exposure to atmospheric factors [1].

The physical environment puts mechanisms of adaptation in place, including acclimatization and biological changes complemented by cultural adaptation [2,3]. In the context of climate change, extreme situations and disruptive changes are forecasted to happen more frequently and intensely in the future. Extreme heat influences morbidity and mortality rates [4,5] mainly in urban areas where most people live. In particular, low temperatures have been associated with respiratory diseases [6,7]. These impacts associated with the lack of thermal comfort are aggravated when extreme values occur several days in a row, forming heat and cold waves. Although the thermal environment has been studied closely, a relationship has also been found with other meteorological factors. For example air humidity has been associated with allergies [8], atmospheric pressure changes with headaches and migraines [9], or biophysical alterations due to atmospheric electromagnetic field variability with neurodegenerative diseases [10].

Most articles published on the subject are based on the definition of standard atmospheric context or stagnant meteorological states or atmospheric contexts, and others are based on the role of extreme weather situations. However, up to now, very few authors have focused on studying the effect of changes in environmental conditions on human health.

In 1973, Gomersall and Stuart analysed the effect of changes in weather conditions on migraine attacks; they found that migraine attacks were less intense than expected when atmospheric pressure was stable or falling rapidly [11]. Along these lines, as an example of a recent study, Szilagyi et al. analysed the relationship between deaths by aortic aneurysm or aortic dissection and the mean daily temperature on the day of death and the change in atmospheric pressure between the day of death and the day before. They found a relationship with daily temperature but the association with the change in atmospheric pressure was not statistically significant [12].

Taking into account the importance of the physiological adaptation of the body to the environment, acclimatization, an anomalous weather change can act as a potential stressor for human health and can compromise people's well-being. This is the theoretical assumption used to propose a method based on an index that numerically estimates the level of distress produced by sequences of changes in weather conditions to which humans are exposed. Under this theoretical assumption, the number of visits to the emergency room, hospital admissions, the rate of infected people in a pandemic and even mortality rate would potentially depend on the existing sequences of weather changes for a given time period. To our knowledge, there is no biometeorological index that proposes a method to assess the change in atmospheric conditions.

The index created whose calculation will be explained later was considered for the first time in a study related to influenza performed in the city of Vitoria-Gasteiz (Spain) [13]. Outbreaks of influenza and the spread of the disease was associated with a higher frequency of changes in atmospheric circulation types. A second study using the same method [14] was developed for the city of Santander (Spain). In this research, the spread of influenza was linked to three parameters of the proposed index using a daily classification of atmospheric circulation types. The hypothesis in both studies was that biophysical distress produced by weather changes depresses the host immune system and makes it more susceptible to infection. Furthermore, changes in atmospheric conditions also affect the pathogen, activating the virus and increasing its virulence.

Method

The proposed method is based on a multiscale index called the Meteorological Contrast Index (MCI).

The MCI is composed by three parameters (diversity of categories, breaks in the sequence and intensity of breakes) obtained from the review of a sequence of atmospheric situations that occur during a specific *calculation period* (CP).

Depending on the environmental analysis variable, its types of fluctuations, and the specific disease under investigation, the chosen CP may vary. It can range from the day (focusing on changes within hours), to analysing the week or the month. In the previously cited articles where the dependent variable was influenza, the chosen CP was the epidemiological week, as it aligns with the timeframe used in the epidemiological surveillance system. The *study period*, therefore, includes many calculation periods within it.

Moreover, a *sequence of categories* to be analysed is also needed. These categories come from the environmental analysis variable, which can be any discrete quantitative variable. In the aforementioned studies, weather types (WT) were the variable which defined the sequence of categories.

Then a *matrix of contrast values* (MCV) must be defined. The MCV represents the magnitude of the meteorological contrast that the change from one category to another implies in terms of biometeorological impact. In the cited example about flu and WT, the WTs were defined depending on the compass rose, allowing 45° per sector, and the change in wind direction between days, allowing the MCV to be defined.

Definition of categories and data sources

The *sequence of categories* must represent meteorological states, must be scalable and preferably its relationship with health processes must have been previously verified. Categories serve as inputs to compute the parameters of the index. They can be defined paying attention to different scientific criteria (Fig. 1), depending on the aims of the study. The use of a catalogue of WT [15], biometeorological [16] or thermal comfort indices such as the Physiological Equivalent Temperature (PET) [17] are some interesting

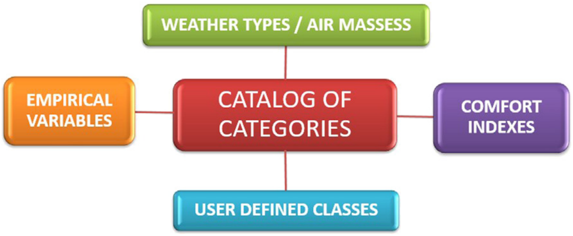


Fig. 1. Defining categories to be used as input for computing the Meteorological Contrast Index (MCI).

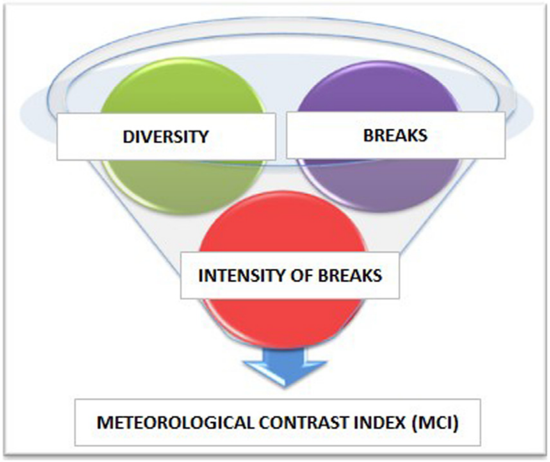


Fig. 2. Parameters of the Meteorological Contrast Index (MCI).

options to define the sequence of categories. For instance, the researcher can define thresholds for temporal series of empirical measurements of atmospheric variables (global radiation, rainfall, temperature) to discretize time series into categories. For example, a time series of air temperature values that ranges from -10º C to + 40º C can be transformed into five categories if a threshold of 10º C is applied.

Estimation of index parameters

The MCI is comprised of three different parameters (Fig. 2) that are complementary. Parameter 1 (P1) refers to the *diversity* of categories recorded in one *CP*. If we have a frequency of one daily record for a calculation period of one week, P1 can reach a maximum value of 7 units when all categories are different, and a minimum of 1 when the same category repeats every day. In *sequence 1*, which is included as an example, we consider some WT as categories. WT are defined taking into account the main wind direction through cardinal points, North (N), South (S), East (E) and so on.

Sequence 1: N – S – E – E – S – S - E → Diversity P1 = 3

Parameter 2 (P2) considers the number of discontinuities there are in the studied sequence in one *CP*. In the example below, the number of discontinuities or *breaks* in the *sequence 1* is 4:

Sequence 1: N **–** S **–** E – E **–** S – S **–** E → Breaks P2 = 4

It is important to point out that similar values of *diversity* (P1) can generate different values of *breaks* (P2) depending on the internal arrangement of categories in the sequence. For instance, sequence 1 and 2 have the same diversity (P1=3) but different P2 values.

Sequence 1: N **–** S **–** E – E **–** S – S **–** E → P2 = 4

Sequence 2: N – N – N – N **–** S **–** E – E → P2 = 2

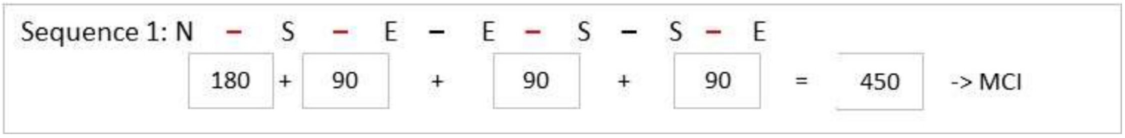
Parameter 3 (MCI), represents the *intensity of breaks* during one CP. In order to compute this value, the MCV must have been previously defined with expert criteria or experimentation. Values in the matrix indicate the relative magnitude of the biophysical impact due to changing from one category to another. This is a key element in the proposed method and its definition is a complex task.

For instance, in the cited papers the categories were WT, which were defined according to the Lamb classification for Northern Spain. In this example, it is assumed that the biophysical impact produced by changing from one category to another corresponds to the number of degrees on the wind rose through the shortest distance between cardinal points. Under this consideration, the MCV is defined by the values in Table 1.

Table 1
Values assigned to biometeorological distress produced by atmospheric changes.

	ATMOSPHERIC CIRCULATION TYPES					
	N	S	E	W	NE	NW
N	0	180	90	90	45	45
S		0	90	90	135	135
E			0	180	45	135
W				0	135	45
NE					0	90
NW						0

According to the values of the MCV (Table 1), accumulated relative impact for the *Sequence 1* is 450 units, which is obtained from the existing transitions between daily categories.



In the example, it is assumed that the value of the change is the same in both directions (North to South is the same as South to North) but this can be modified when there are biophysical reasons that indicate different values for different changes. Values of matrix should be determined with experimentation in labs where environmental conditions can be controlled, and biophysical impact measured.

Conclusions

Most of the published studies analyse the relationship between meteorological factors (single variables or indices calculated from evaluation of the combined effect of different factors) and human morbidity and mortality. However, acclimatization, understood as the physiological adaptation of the body to the environment at a specific time, is essential for the proper functioning of the body [18–20].

The distress produced by weather changes is undoubtedly a factor to consider in public health policies in the frame of impacts and adaptation to climate change. With this context, this work proposes an easy-to-calculate index that not only addresses atmospheric changes but also the intensity of those changes. New studies should be developed to evaluate the predictive value of the MCI for different diseases and in different geographic areas with different climatic conditions.

If the predictive value of this index is verified, it could be useful to define biometeorological early warning systems in order to prevent certain diseases or their aggravation and to manage health resources in the near future.

Ethics statements

There is no any ethics issue to consider.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Tápanes-Robau Daysarih: Investigation, Writing – review & editing, Writing – original draft. **Santurtún Ana:** Visualization, Investigation, Supervision, Writing – review & editing. **Fdez-Arroyabe Pablo:** Conceptualization, Methodology, Investigation, Writing – review & editing, Validation.

Data availability

No data was used for the research described in the article.

Acknowledgments

None.

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