VILNIUS UNIVERSITY

Judita Liukaitytė

QUANTITATIVE EVALUATION OF BIOMETEOROLOGICAL CONDITIONS IN LITHUANIA

Summary of doctoral dissertation

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VILNIAUS UNIVERSITETAS

Judita Liukaitytė

BIOMETEOROLOGINIŲ SĄLYGŲ LIETUVOJE KIEKYBINIS VERTINIMAS

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Introduction

The effect of weather and climate on health and well-being has been known for 2,500 years. Research carried out in many countries around the world show that weather not only effects human well-being but also can cause various diseases or disorders. People have different sensitivities to weather: meteo-labile individuals are quite sensitive to weather changes (for example, they feel headaches, joint pain, scar pain etc.), some people do not feel any weather effect (meteo-stabile). A number of studies have been carried out in order to determine the impact on human health from atmospheric fronts, various air masses and some geophysical factors.

Weather effects public health with the most frequent extreme natural events resulting in loss of human life being cold and heat waves. Each year more people die from “excessive heat events” than from hurricanes, lightning, tornadoes, floods, and other meteorological disasters combined. It is important to inform people about the impending disaster in time and explain how they can protect themselves. Biometeorological forecasts provide preliminary information about the health risks resulting from the heat and cold waves during sudden or extreme weather changes. They also cover increased ultraviolet radiation, when prolonged exposure to the sun becomes dangerous and forecasts of air pollution and pollen.

Biometeorology is still a young science in Lithuania. So far, very little has been done on the impact of weather on human health. Many aspects of the problem are not yet completely analyzed. With this research the author hopes to contribute to a wider cognition of the analyzed problem and to create a basis for dissemination of biometeorological information through the establishment of forecasting system.

The subject of research

Biometeorological environment of Lithuania

Aim of the research

Determine the weather impact on human health in Lithuania and accomplish evaluation of biometeorological conditions in the country.

The goals of the research:

1. Carry out a sociological evaluation of weather sensitivity in the Lithuanian population;

2. Measure the impact of the weather conditions on cardiovascular disease recurrent in Vilnius;
3. Analyze changes in the Humidex and Wind Chill indices change in Lithuania;
4. Assess the effects of heat on mortality of the population of Vilnius;
5. Perform a calibration of ultraviolet radiation values measured in Kaunas MS;
6. Assess the appropriateness of the STAR model for forecasting of UV radiation intensity in Lithuania.

Defended statements

1. Weather conditions and their changes affect public health in Lithuania. The number of cases of cardiovascular disease depends on weather conditions and can be predicted on the basis of a relationship with meteorological parameters.
2. Thermal indices provide important additional information about biometeorological conditions of the territory. The Wind Chill index is appropriate to use for predicting the effects of cold and the Humidex index is appropriate for predicting the effects of heat.
3. Mortality increases during heat waves. Consequently it is necessary to have a warning system of heat impact on public health.
4. The STAR model is appropriate to perform the calibration of UV data and can be used to calculate and forecast the intensity of UV radiation in Lithuania.

Novelty of research

In this research for the first time in Lithuania 1) a sociological survey on the weather impacts on public health was carried out; 2) the impact of meteorological conditions on patients with cardiovascular diseases in Vilnius was measured; 3) spatial and temporal changes in thermal indices were analysed; 4) the effects of heat on mortality of the population of Vilnius was assessed; 5) the relevance of various biometeorological heat indicators for warning the inhabitants about heat was estimated; 6) the appropriateness of the STAR model for forecasting of UV radiation intensity in Lithuania was evaluated.

Relevance of the subject matter

As understanding of climate and weather effects on humans has improved, more and more attention has been paid to this field, especially in national weather services. Many of them provide forecasts and information on how to adapt to meteorological conditions that are unfavorable for health and how to reduce the environmental impact and stress caused by it. Forecasting methods discussed in the thesis can be used in the Lithuanian Hydrometeorological Service under the Ministry of Environment for making biometeorological forecasts. The research will help to develop the spheres of health resort medicine and public health. On the basis of this work, improvements can be made to the existing early warning system of natural disasters, catastrophic and other dangerous hydrometeorological events. There also is a possibility to create a heat-health warning system to inform the general public about heat effects on health. This research is a contribution to studies on climate change impacts on human health and can be used to improve the strategy of adaptation to climate change.

Extent and structure

The doctoral dissertation is composed of: an Introduction; seven main chapters; Conclusions; a list of references; a list of individual publications on the dissertation subject; and an annex. The dissertation comprises 133 pages. It contains 18 tables, 76 figures and 172 references to literary sources.

Approbation of results

The dissertation results were reported at six international and ten republican conferences: 4th European Conference on Severe Storms (Trieste, Italy, September 10-14, 2007); two presentations in The Second Saint-Petersburg International Ecological Forum „Environment and Human Health“ (Saint-Petersburg, Russia, July 1-4, 2008); 18th International Congress of Biometeorology (Tokyo, Japan, September 22-26, 2008); Third Biannual NCAR Workshop on Climate and Health (Boulder, CO, USA, July 13-17, 2009); WMO Planning Meeting on Heat-Health Warning Systems (Shanghai, China, July 21-24, 2009); 7th BIOMET Conference (Freiburg, Germany, April 12–14, 2010); republican scientific conference "Meteorology and Hydrology in Lithuania: Development and Perspective" (Vilnius, March 3, 2005); 4th scientific conference „Science at the Faculty of Natural Sciences“ (Vilnius, November 23-24, 2006); 9th conference of young Lithuanian scientists „Science is the future of Lithuania (Vilnius, March 30, 2006); workshop "Climate change: adaptation to its impacts in Lithuanian coastal area" (Klaipėda, May 4, 2007); 11th conference of young Lithuanian scientists „Science is the future of Lithuania“ (Vilnius, April 3, 2008); LHMT conference „Weather and climate effect on human health“ (Vilnius, April 10, 2008); 12th conference of young Lithuanian scientists „Science is the future of Lithuania“ (Vilnius, April 2, 2009); VASC workshop „Climate change and human health“ (Vilnius, September 15, 2009); 13th conference of young Lithuanian scientists „Science is the future of Lithuania“ (Vilnius, March 25, 2010); 3th national scientific conference „Science for human health“ (Kaunas, April 7, 2010).

Publications

The dissertation results were published in 13 scientific articles. Three articles were published in journals included in the international databases.

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Methods and data

Methods of the research of weather impacts on cardiovascular morbidity in Vilnius. The first chapter is aimed to evaluate dependence of the incidence of some disease recurrence on meteorological conditions in Lithuania. Data used in this part are collected from daily emergency call tables of the Vilnius ambulance station. Analysis was performed on data from years 2007-2008. Only diseases for which annual incidence exceeded 300 cases were selected.

Also data were used from Trakų Vokė meteorological station, obtained from archives of the Lithuanian Hydrometerological Service. Some variations of parameters (average, minimal and maximal air temperature, atmospheric pressure, wind speed and relative humidity) from day to day were calculated. These data were used to establish the main weather class of the day, which could have impact on human health. This work utilizes a medical-meteorological weather classification developed in the German Weather Service (DWD).

Every illness was analyzed using several methods: reviewing annual variations and correlation with meteorological information; analyzing homogeneity by Student's criteria.

Methods of the research of thermal indices. On the basis of thermal indices national meteorological services present the forecasts of felt temperature and inform people about comfortability or the level of cold and heat stress outside. The Lithuanian Hydrometeorological Service under the Ministry of Environment started forecasting the heat index „Humidex“ in summer 2008, and the Wind Chill in winter of the same year.

The research: estimated the level of thermal discomfort caused by heat and cold in Lithuania; assessed dynamics of „Humidex“ index values in summer and Wind Chill in winter; determined territorial differences; and estimated the daily rate of the indicator. Also, the research evaluated the weather conditions that determine extreme values of the indices.

The research analyzed values calculated by methodology developed by Canadian scientists for calculation of heat discomfort, so called the „Humidex“index. The human body feels a higher or lower temperature compared to real air temperature depending on the air humidity. The gradation of possible health effects presented by Canadians was slightly modified in this research: <27 °C – no discomfort; 27-32 °C – slight discomfort sensation; 32-37 °C – strong discomfort; 37-42 °C – strong indisposition sensation; >42 °C – serious danger. Heat exhaustion is possible with prolonged exposure and physical activity when the apparent temperature exceeds 32 °C. Such high temperatures can be observed from the end of May till the beginning of September in Lithuania. For this reason only summer months were analyzed in this study. Daily index mean values were estimated as the average of four daytime measurements (12 AM, 3, 6 and 9 PM).

„*Wind Chill*“ index (WCT) – describes the temperature and wind effects on human comfort. The index shows the temperature felt by a person, i.e. a temperature that will be felt by uncovered body parts at low temperature and wind stronger than 1,5 m/s.

Although the index includes only these two parameters, wind and air temperature are the key elements that affect the human thermal comfort during the cold season. A strong wind blowing during the cold season will lead to a lower felt temperature than real air temperature. With more than 5 degrees Celsius or wind weaker than 1.5 m / s wind, the wind does not chill.

Values analyzed in this study were from the period of 1993-2006 in Lithuania. This fourteen-year period is sufficient to make the original findings of thermal comfort conditions in different regions of Lithuania.

For the calculation of „Humidex“ index air temperature and relative humidity data were used. For Wind Chill the air temperature and average wind speed were used in the research. Data of the synoptic situation occurring simultaneously with the extreme indices values were selected on the basis of surface analysis charts and different pressure levels maps. According to them the weather situation of particular days and the directions and intensity of advection were identified.

In order to implement a Heat-Health warning system it is necessary to correlate meteorological data with medical data and determine the most appropriate indicator to describe the heat stress on humans. There are six heat indicators used in this chapter to study the relationship with mortality data. Initial data used covered the years 1993–2007 (June–August months) with daily Vilnius (Trakų Vokė) MS data (relative humidity, air temperature, wind speed, total cloudiness). Daily mortality data of the same period, collected by Vilnius City Civil Registry Department, were also analyzed.

Heat indicators used in the research:

- *Air temperature*. The data of maximum**,** minimum and mean air temperature are used to assess the heat stress. There are four danger levels of the heat stress based on deviations from the average. According to the operating laws of Lithuania heat does not cause a risk because it is not on the list of the hazardous events. It immediately becomes a natural phenomenon - swelter (maximum temperature ≥ 30 °C, duration ≥ 10 days) Unfortunately, its effects on health can not be determined because it has not been in Vilnius over the entire period of the measurements.

- *Humidex index*.

- *Heat index (HI)*. This index like "Humidex” is calculated on the basis of air temperature and humidity values.

.- ***Physiological Equivalent Temperature (PET).*** This index is based on the heat balance equations and is calculated by "Rayman" program. Calculations already include more meteorological data: air temperature (^oC); relative humidity (%); wind speed (m/s); total cloudiness (oktas).

Table 1. Levels of danger caused by heat based on mean, maximum and minimum air temperature, Humidex, HI and PET.

HEAT LEVEL	**Mean temperature, ^oC**	**Maximum temperature, ^oC**	**Minimum temperature, ^oC**	**Humidex, ^oC**	**HI, ^oF**	**PET (^oC)**
I. Possible health risks	21–23	27–29	15–17	27–32	80–90	23–29
II. Health risks	23–25	29–31	17–19	32–37	90–105	29–35
III. Serious health risks	25–27	31–33	19–21	37–42	105–130	35–41
IV. Emergency situation	> 27	>33	>21	>42	>130	>41

All heat indicators describe stress of the human body caused by heat. Some of them include into calculations main meteorological elements that cause heat discomfort and present the results as one value describing the heat stress.

In the next part of the research values of heat indicators are linked to the mortality data in Vilnius. To find out what effect heat has on human health the probable mortality of each day was calculated. Probable average mortality for summer periods of years 1993–2007 was calculated using moving average of 31 day. Calculation of this moving average requires the mortality data of one month before (May) and one month after (September). Since daily mortality data of the year are only from the period 2003–2007 averages of this period were calculated eliminating very high and very law mortality values. To avoid the difference in further calculations resulting from the unequal number of deaths in different year data were standardized. These standardized values were used to calculate probable mortality of each summer day for the period 1993–2007.

Further research analyzed parameters of description of thermal environment and heat effect on mortality. The daily number of deaths recorded in Vilnius is changing from 3 to 28 deaths a day. In order to relate high mortality values with the heat effects heat periods were identified.

Heat is considered to be the time period when at least one indicator three consecutive days and the second indicator at least two consecutive days reached the second level of the heat alert. A period when two and more indicators comply with these rules is called the **heat wave**. Heat wave ends when the last indicator which identifies the heat wave three consecutive days does not reach the second level of the heat alert.

The heat period includes two days before and two days after the heat wave to verificate if there was not significant increase in the amount of death before and if effect does not occur after the heat ends.

The research estimated the increase in mortality (the difference between actual and expected mortality) during the selected periods of heat. Mortality rate during the heat period was calculated averaging the proportion between actual and expected mortality of each day of the heat period.

To find out the mortality changes the averages of deaths were calculated two days before the heat wave, two days after the heat wave and during the heat wave. As the heat waves lasted the different amount of days, the average was calculated for days when at least three heat waves still continued. This method of calculation was also used to find out the mortality changes according to the different indicators.

Methods of UV radiation data calibration and UV changes in Lithuania. With difference to the previous chapters this is not intended to justificate biometeorological forecasting. In Lithuania there are used UVI forecasts given free by German Weather Service. The more serous problem is faced trying to compare the data. Measured data differ from forecasted because of spectral sensitivity of measuring devices and sensitivity errors of angular sensor, it causes difficulties in comparison of the data. That is why it requires calibration of the data, i.e. determination of systematic errors. This chapter describes the method of calibration which is appropriate to use in Lithuania and compares measured and calculated values.

The aim of the work was to make the calibration of quantities measured by the STARsci model, to make the calibration of the data measured at Kaunas MS in 2001–2002, to make the matrix of the calibration and to find the single calibration constant. In Kaunas meteorological station UV radiation is measured by UV – Biometer 501A . The data from User‘s Guide about spectral and angular sensitivity of the sensor is used in the research. Calculations were made using STARsci model in different atmospheric conditions.

The solar zenith angle is significant with respect to cosine weighting but also to the spectral composition of the irradiance, and the ozone content shifts the intensity and thus is significant for spectral weighting. After the analyzing the influence of albedo and aerosol optical depth on the calibration matrix it has been established that the change of the parameters has nearly no influence on this matrix, therefore these quantities remain constant**.** In the research there were used maximum daily erythemal radiation values, which were calibrated. So, according to the ozone content value and solar zenith angle at the moment of maximum separate calibration matrix was applied to every quantity.

However, complete calibration requires not only calibration matrix but also general constant of calibration. Assuming that the instrument did not change its characteristics within years of exploitation general constant of calibration was found by comparison of measured and multiplied by calibration matrix values with simulated values. It was done on the basis of erithemal radiation indicators of 2001–2002 years, measured and simulated on clear days. Obtained slope was used as general calibration constant and in accordance with it calibration of measured indicators was carried out. To make the complete calibration the peak erithemal radiation data measured by Kaunas MS is multiplied by calibration matrix and general calibration constant.

After calibration of the data measured in Kaunas MS the comparison of calibrated and simulated data was accomplished. Erithemal radiation was simulated by two versions of STARneuro model. The relationship graphs of the data measured by STARneuro model and the data measured in Kaunas were made.

Comparison of the data was accomplished separately on clear, cloudy and overcast days. It was verified which version of STARneuro model is better to use on cloudy and overcast days.

Sociological evaluation of human sensitivity to weather

When beginning to publish new specialized weather forecasts or improving the existing ones, it is very important to find out the needs of their users. In order to improve the format of presentation of the weather forecasts and to supplement them with biometeorological forecasts, in 2005-2006 in Lithuania a popular survey was carried out requesting respondents to assess the presented forecasts and to answer additional questions about their sensitivity to weather conditions, their perception of comfortable weather conditions, etc. For the purpose of obtaining more exact data and performing qualitative analysis, 500 respondents were surveyed in all the regions of Lithuania. Respondents were chosen by their age, education, work, living place, etc.

Only 26 % of all respondents said that weather had no impact on their health, or were not sure if their state of health had ever worsened in response to meteorological situation. Every second Lithuanian inhabitant considered weather to be influencing the state of human health. The vast majority of respondents, i.e. about 55 % were of the opinion that weather had some influence on their health, while some 19 % considered weather to be influencing their health strongly. The most weather-sensitive were respondents over 60 years of age. As many as 35 % of respondents felt sensitive to moist weather, 27 % felt adverse impact on their organism of the weather cooling down and 12 % of respondents felt influence of the stormy weather. It can be stated that people are most sensitive to weather caused by low-pressure field when the humid, stormy weather is dominated and after the cold weather front the weather suddenly cools down.

Also it was checked what difference it makes when the weather does not change for a while or changes constantly and since when the sensitiveness occurs. People were more sensitive to changeable rather than persistent weather, the most influential being vast variations of temperature.

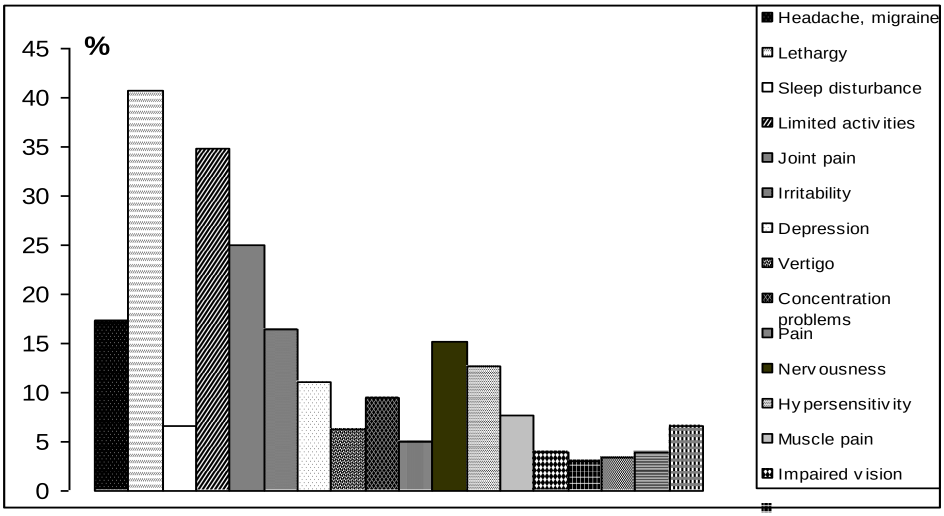

Fig. 1. Frequency of symptoms of weather-sensitive subjects

Weather impact is mostly associated with joint pain, limited activity, fatigue and lethargy. Respondents also indicated additional disorders originating from weather conditions, such as allergy, coryza, respiratory diseases, change of moods, nervousness, etc (Fig. 1.).

The results were compared with the similar researches of German and Canadian scientists. Significant health effects are felt by 19.2 % of German and Lithuanian population. Some effects occur to 35.3 % of Germans, and even to 55 % of Lithuanians. The summary of the results shows that 54.5 % of the German population are sensitive to the weather, 61 % respondents of Canada feel weather effects on their health, and in Lithuania 74 % of the population feel that the weather affects their health. Lithuanians are most sensitive to wet and colder weather.

Having analysed responses regarding comfortable weather conditions it was established that as many as 58 % of responders considered to be comfortable those summer days with maximum air temperature varying between 23–26 ºC and the most comfortable being from 19 to 22 ºC. An interval between 27–30 ºC was selected by merely 14 % of the respondents. Comfortable summer nighttime temperature was considered to be within 13–16 ºC and 17–20 ºC intervals, according to the equal groups of 40 % Lithuanians. The most favourable weather was considered to be clear or slightly cloudy with light to moderate winds, in nighttime as well as in daytime. Remaining wind speed categories were considered to be discomfortable. In the opinion of the most respondents (42 %), comfortable wintertime conditions comprised prevailing clear and slightly windy weather with air temperature varying from -5 to -9 ºC.

A survey was carried out in order to find out what additional information is still needed for the Lithuanian people. For more than 50 % of the respondents relevant information is about air pollution. More than 30% of the respondents would like to receive information about the weather impact on their well-being. The respondents also consider information about ultraviolet radiation as being very important (27 %).

Many people consider biometeorological forecasts being necessary, but the start of the publication of new forecasts should be followed by wide information to the public about the benefits of such forecasts, where they are published and how to apply them in everyday life.

Relationship between human morbidity and meteorological conditions

Before the publication of medical-meteorological forecasts it is necessary to determine the dependence of the frequency of diseases recurrence on meteorological factors in Lithuania. 11 cardiovascular diseases were analyzed according to their distribution in a year and dependence on meteorological elements or their complexes. In the period 2007-2008 in Vilnius most recorded cases were of arterial hypertension, unstable angina and stroke (>5000).

Studies have shown that in many countries cardiovascular diseases have clear annual course – peak is in cold and decline is in warm season. Winter is unfavourable season for patients of cardiovascular disease; it could be related with increase in blood viscosity and vascular stenosis. In summer the number of calls on many of these diseases decrease, it could be related with warmer climate which has a positive effect on heart diseases, as well as with increased number of holiday makers in the countryside.

Analysis of the data of ambulance emergency calls in Vilnius shows that the number of cases of arterial hypertension, cardiopathy, acute miocardial infarction and paroxysmal tachicardia statistically significantly decrease according to mean, maximum, minimum and dew point temperature values. The obtained correlation coefficients are statistically significant. Arterial hypertension is also related with Sunshine duration – the number of cases decrease, but accordingly to the average wind speed the number of cases increase. Minimum air humidity is related with increasing of cases of miocardial infarction, while interday shift of mean and minimum temperature is related with cardiopathy. Other disorders of permeability statistically significantly correlate only with air pressure, its increase causes decrease of the cases. Other cardiovascular diseases have not statistically significant relationship with meteorological parameters.

Using Student's criterion there was checked whether the number of calls does not increase under certain meteorological parameters values.

In many cases all complex of meteorological parameters has impact on the diseases. Summarising the data shows that arterial hypertension flares up when the average temperature is bellow 0 °C and average wind speed is more than 4 m/s. That means this disease could be stimulated in cold season by decrease of felt temperature caused by wind chill. On the other hand, calculations based on multinomial regression shows that most frequently exacerbations of disease could be caused by complex of mean daily and dew point temperatures. Regression was influenced by some other parameters (wind speed, sunshine) but their input into reasoning of total dispersion was not significant. So, the main elements influencing the disease would be mean and dew point temperature, it could be stated that the disease depends on hygrothermal conditions. Blood pressure statistically significantly increases when the weather is determined by the third weather class (down slide motion at the edge of an anticyclone) – when after better antyciclonic weather pressure slightly drops and bigger weather changes approach. Complex relationship between temperature and humidity could also be explained because when low pressure field approaches humidity increases and temperature falls.

Cardiopathy cases increase when wind speed is more than 4 m/s, weather temperature is below -5 °C (increase is also noticeable when mean temperature is 10–15 °C). For cardiopathy patients the most favourable temperature is 0–5 °C and the days are without precipitation, then the number of emergency calls decreases. The number of cases statistically significantly increases with prevailing weather class 9 - easterly air flow.

Strong relationship was noticed between unstable angina and weather class 9 too. Multinomial regression showed that exacerbations are influenced by complex of maximum daily temperature and sunshine duration.

The number of cases of miocardial infarction increases even 29 %, when air pressure is higher than 1010 hPa. The number of emergency calls increases when temperature fluctuates between 0 and -5 °C, below -5 °C – their number increases even more, the number of cases decreases with prevailing mean air temperature 0-10 °C . So, this disease is related with cold weather determined by higher air pressure field. Although relationship with any weather class is not found probably there is an affect of Arctic anticyclones that often determine the weather in winter. One more important factor should not be dismissed – air pollution, which mostly increases in such weather conditions and is related with exacerbation of many cardiovascular diseases.

Analyzing input of specific parameters to exacerbations of paroxysmal tachycardia it was found that high air pressure >1010 hPa has negative input, while with temperature values 0–5 °C there was recorded the least number of cases. The number of emergency calls increases when the weather gets colder. According the model of multinomial regression paroxysmal tachycardia is influenced by complex of minimum daily temperature, the amount of precipitation and the shift of maximum daily temperature. Patients of this disease should be careful with weather class 3, when it is prevailing the number of cases statistically significantly increases. Thus, the disease responds into starting weather changes when high pressure starts falling but the weather stays cold.

Atmospheric pressure has an impact on exacerbations of Cardiac permeability disorders. When pressure is lower than 980 hPa, a number of emergency calls increases, under the conditions of pressure higher than 1010 hPa it decreases. Complex weather impact on exacerbations of Cardiac permeability disorders has not been established.

When the atmospheric pressure drops below 980 hPa, a number of emergency calls for atrial fibrillation or flutter significantly increases (12 % of the total average). Wind of average speed more than 4 m/s has negative impact on exacerbations of the disease. The number of cases of atrial fibrillation or flutter statistically significantly increases under the conditions of weather type 10, i.e. when the weather remains stable for a longer period of time and after it is determined by a lower pressure field. So, most probably this disease has an incubation period after which it develops in a few days when cyclone centre moves away from Lithuania.

Heart insufficiency is little influenced by atmospheric processes. Statistically significant relationship was obtained only with an increase in the number of emergency calls and more than 8 mm precipitation per day. Wet weather has effects on the increase of brain infarction. More emergency calls are recorded when precipitation is more than 8 mm per day, with relative humidity >80 %. A number of brain infarction increases under the conditions of weather class 5, which is described as „warm cyclone sector“. At that time the weather is usually wet and warmer than it was before.

A number of stroke cases is not statistically significantly related with any of meteorological elements. It statistically significantly increases only under the conditions of weather class 4 („warm air advection in front of a cyclone “)

After the calculations it became clear that chronic ischemic heart disease has not direct correlation with any of meteorological parameters. Statistically significant relationship was not found even after evaluation by the model of multinomial regression.

Thermal indices changes and their application in Lithuania

Heat index changes in Lithuania in 1993–2006. High-average "Humidex" index values are recorded in all over Lithuania during the period from July the second till August the first five-day period. Last three five-days of this period are preeminent when the maximum of average values stabilise (the largest in Panevezys, 26.1 °C). The index values in different cities of Lithuania which are further from the sea differ very little and fluctuate very simultaneously.

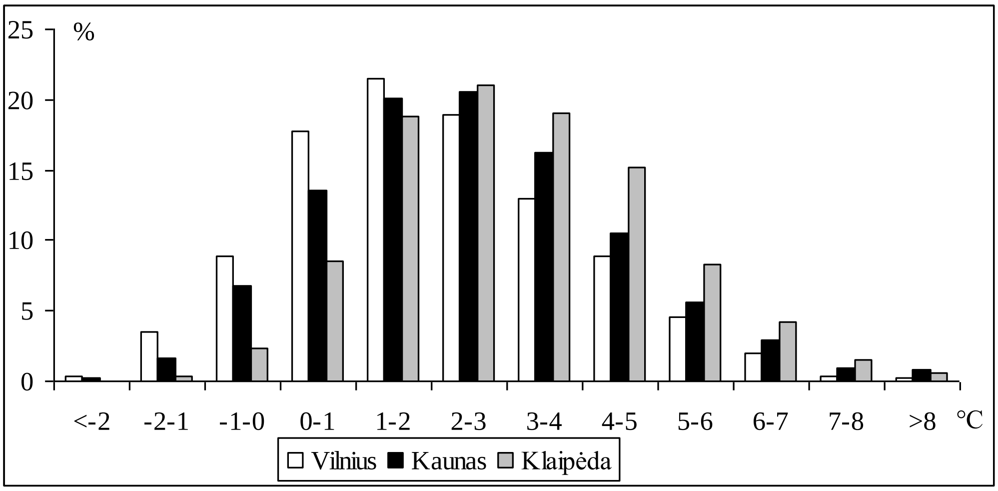

Figure 2. The difference between the measured air temperature and Humidex during the summer months in Vilnius, Kaunas and Klaipeda in 1993-2006

The difference between "Humidex" index value and the measured temperature of the test period during the summer months in major Lithuanian cities is not significant. In Vilnius modal interval is 1-2, in Kaunas and Klaipeda, 2-3 °C. In Klaipeda more often than in other areas this difference is more than 4 °C (> 15 % of cases). This is due to significantly higher values of air humidity in the daytime at the seaside. In rare cases, this difference can exceed 8 degrees. In Vilnius there were recorded the most cases (14.2 %), when index value coincided with an air temperature. Coast moisture content is higher, so in Klaipeda there were just 3.2 % of cases, when felt temperature did not exceed the measured in summer days.

Adverse health effects or discomfort are caused by felt temperature increase to 27 °C. It was found that the number of days on which at least in one of the measurements terms the threshold value is reached, is an average from 22 % (Klaipeda) to 31 % (Panevezys) of the total number of days in the summer. Greater impact on health and which poses severe discomfort higher than 32 °C are less frequent: approximately 4.5 to 8.8 % of the total number of days. Hazardous to health temperatures (> 37 degrees C) do not occur every year and accounts for only 0.8 to 1.4 %. Throughout the whole period there were recorded 18 episodes (32 days), when in one or more analyzed areas the index values were above 37 °C. During the analysed period a felt temperature was higher than health-threatening 42 ºC twice.

Maximum number of days with extremely high values recorded in July (22 days), in June and August such events are relatively rare (respectively 4 and 6 days).

After the weather analysis of those days it appears that in many cases, high "Humidex" index values were fixed when at 500 hPa isobaric surface over Lithuania were high-altitude anticyclone ridge (56 % of cases). High-altitude Anticyclone caused such weather in 31 % of the cases, while the remaining 13 % of the cases are associated with high-pressure field (high-altitude anticyclone periphery).

On the surface even 18 days, extremely high-index values were recorded in the front periphery of the approaching cyclone. At that time in the altitude of 850 hPa isobaric surface heat ridge is formed, hot, humid tropical air is swept from the south, the air temperature in the altitude is more than 15 degrees, while the maximum heat zone is slightly southward of Lithuania.

Higher-pressure field caused such weather five times. At that time the anticyclone centre was eastward of Lithuania. As in a previously discussed case, in the altitude of 850 hPa isobaric surface heat ridge was formed, warmth of 13 to 15 degrees Celsius was brought from the south.

9 days such weather was caused by Anticyclone, centred in the north-east of Lithuania. Anticyclone centre was at 500 hPa isobaric surface over Lithuania. Although in the altitude of 850 hPa isobaric surface the heat ridge was formed, the temperature was much lower than in case of cyclone periphery or a higher-pressure field.

Cold index changes in Lithuania in 1993-2006. Low average Wind chill values are recorded in Lithuania during the period from January the forth to December of the first five-days, also low-value was determined on the fifth five-days of January. Minimum average index values occur in many cities during this period (the lowest average Wind Chill in Vilnius -10.2 °C). Wind Chill values in the cities of Lithuania which are further from the sea differ very little and fluctuate very simultaneously.

The difference between the Wind Chill and measured temperatures in the analysed winter months in major Lithuanian cities usually is not small. In Vilnius modal interval is -3 ...- 4 °C, in Kaunas and Klaipeda -4 ...- 5 °C. In Klaipeda much more frequently than in other areas, the difference exceeds 5 °C (~ 40 % of cases). In rare cases, this difference can exceed 10 degrees (Fig. 3.).

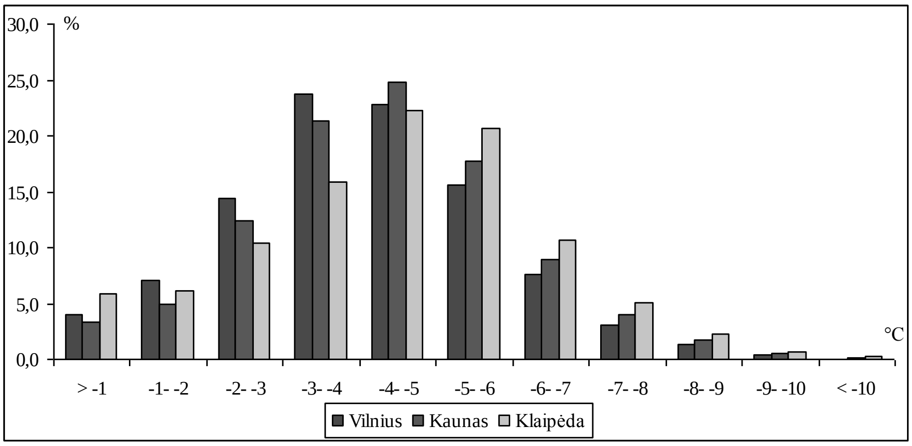

Figure 3. The difference between the measured air temperature and Wind Chill during the cold season in Vilnius, Kaunas and Klaipeda in 1993-2006

It was found that the number of days on which at least in one of the measurement time-limits is reached the threshold value -10 °C, is an average of 23 % (Klaipeda) and 36% (Vilnius) of the total number of days in the cold season. When the minimum air temperature drops below -25 °C there is achieved the criteria of dangerous phenomenon - cold. The cases when the Wind Chill Temperature is below this threshold are less frequent: approximately 0.8 to 3% of the total number of days in the cold season.

The absolute minimum of the reference period was recorded December 27, 1996 in Vilnius -38.6 ° C. At that time, a very low index values were fixed in other cities too. In all cases, when there were recorded the lowest values of Wind Chill, weather in Lithuania was resulted by arctic anticyclones, which centre was over or close to Lithuania.

The effects of heat on mortality in Vilnius in 1993-2007. There were analyzed daily mortality data of three summer months of the 1993-2002 period, and daily data for the entire year of the period 2003-2007 in Vilnius. During the period, there were identified 23 periods of heat. Four years were without heat periods, in other years there were from 1 to 5 heat periods per year. In all cases, one of the indicators was the PET index, however, this index indicate the heat waves even when the other indices did not indicate them. To avoid many false alerts, Lithuania heat levels by PET should be distinguished only from 29 °C, and category of average physiologically heat stress should be split into two parts. There occurred only 11 HI values of the second level (hot) and no one higher. In addition, the index indicated and other hot periods, when it was a danger of level 1. PET and HI indices could be used in the heat warning systems after changing the heat levels of risk. The "Humidex“ index has identified a number of heat periods, it is quite good and precise indicator.

Values of the extreme levels for the minimum, maximum and average temperatures were distinguished on the basis of values repetition in period 1993 - 2007. The minimum temperature reached level of extreme > 21 °C on 2 days, maximum > 33 °C – on 12 days, mean > 27 °C - on 3 days. Extreme values of indices were determined according to their heat alert levels.

In the paper daily mortality is associated with the expected mortality of the reference period. The expected mortality rate indicates the average number of people dying during the analyzed period in Vilnius. In accordance with it there is possible to determine whether mortality increases during the heat waves.

It is necessary to assess after how many days of continuous heat the health effects start. Summarizing the data of all 23 periods, it was obtained that the heat effect already starts on the second day of a heat wave, then the first peak of mortality occurs, the number of deaths increases by 15 %. Later mortality rates remain higher than expected, while the second peak occurs after 7 consecutive days of the persistent heat, the number of deaths increases by 24 %. After a heat wave during the next two days mortality is decreasing, on the second day it already become lower than expected mortality. On this basis, it can be said that if the heat lasts for at least two days, it is necessary to announce the heat alert as there is a hazard to health.

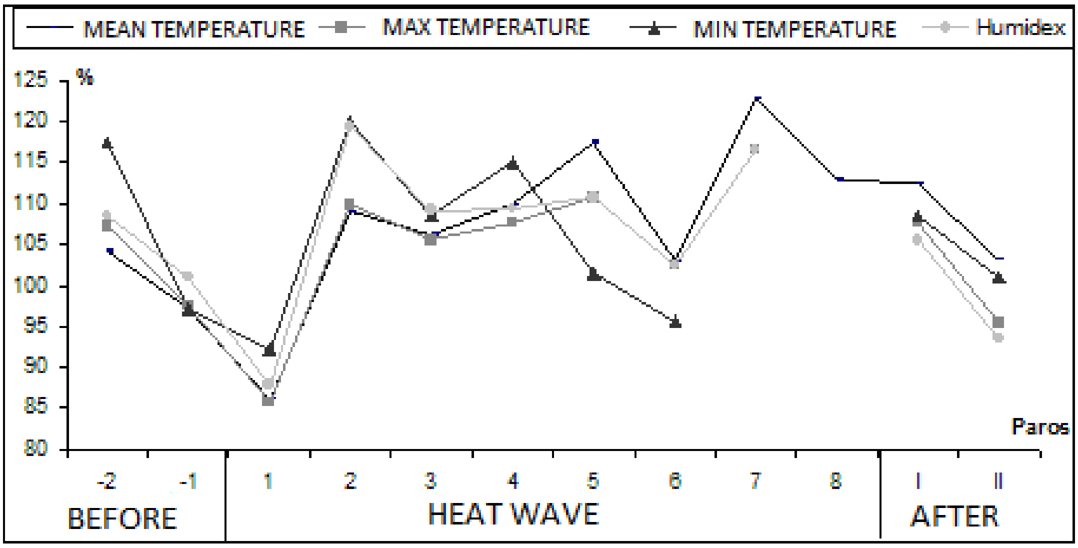

Figure 4. Mortality changes according different indicators (%), 2 days before heat wave, in heat wave period and 2 days after heat wave in 1993–2007

Thermal sensitivity of the scale should be changed for „Humidex "index too, if you want to use it as a key indicator to announce the heat alert. Extreme risk to health should be announced when the "Humidex" index reaches 37 °C. The minimum temperature is quite a good indicator, but it would be appropriate to use in conjunction with the maximum temperature. During the heat wave the biggest health risk occur when there is very hot in day and not cool enough at night, then there is no time for the body to recover. In all cases the average temperature indicated heat similarly to the maximum temperature. Since the maximum air temperature is easier to predict, and it is presented in all the weather forecasts, it would be the most appropriate to indicate the heat waves.

Heat-healt Warning Systems (HHWS) in Europe. The paper provides information about the heat-warning systems existed in Europe in 2009. Data was obtained from the National Hydrometeorological Services (NHMS) sites or receiving the information in official letters. Information was collected about what indicators are used in the countries to announce the heat alert, what are the risk levels, the differences of criterions of the heat risk in the different regions of the country, what is the period to announce the heat warnings.

30 countries declared heat warnings in 2009. Most of HHWS provide warnings to the whole country, except Italy and the United Kingdom (UK). In Italy the warnings are provided to the cities with more than 200 000 inhabitants, while Meteorological Service of UK provides them only to Wales and England. An important indicator is led time, i.e.

how long before the people and authorities are informed of the expected heat wave. Most often the warning is provided 24–72 hours before, but there are countries where the warnings are provided earlier – Spain, the Netherlands and Belgium provide the warnings with led time of 5 days. HHWS often works only in summer, because then there is the risk of the heat waves. In Germany and Serbia it starts working in April, in other countries – in May-June, it usually finishes in September. The longest period the system is activated in Serbia – till the end of October. In many countries there is no defined period of time the system works, just if there is a heat danger then the warnings are posted.

The maximum temperature is a key indicator by which the heat warnings are provided in most of the countries: Belarus, Greece, Latvia, Estonia, Ireland, Croatia, Czech Republic, Luxembourg, the Netherlands and Serbia. Only values differ which are announced as a risk in particular countries. The lowest threshold temperature is in Ireland, in the northern part of the country the first level heat risk is announced at 23 ° C, while in Greece the warning is provided only when the maximum temperature rises to 39 ° C. Estonia, Latvia and the Netherlands require that the heat episode would last of the certain number of days. The Netherlands provide the heat warning if maximum temperature of 25 °C is forecasted for 5 days consecutively, Latvia - if maximum temperature rises to 27 °C 6 days consecutively or one day it rises to 33 °C. Czech Republic and Estonia require two days of maximum air temperature of 30 °C. Czech Republic also announces heat risk if the maximum temperature of one day is 35 °C.

Portugal has quite unique HHWS system with a number of indicators of the heat alert for the announcement of warnings. Although mostly it is based on the maximum values of temperature, ICARO index and many other methods are used during the heat waves. Even if the threshold temperature values are not reached in cases of fire, high UVI or other factors forecast centres can announce the heat hazard.

Luxembourg alerts to the health sector, if the next four days temperature is expected higher than 29 °C, moreover, the night temperature should remain fairly high. Hungary uses the mean temperature as an indicator of the heat danger to be announced. If three consecutive days the mean temperature reaches 25 °C or for one day 27 °C, the heat risk is announced.

Another widely used method is the combination of minimum and maximum temperatures. On this basis, the alerts are provided in Belgium, the United Kingdom, France, Poland and Spain. Only if both parameters reach a threshold temperature value, the country provides a heat alert warning. The minimum temperature range for the heat risk announcement differs from 15 °C in some regions of the United Kingdom to 25 °C in some regions of Spain. Accordingly, maximum temperature differs from 28 °C to 41 °C. In Belgium and the UK a risk of heat is announced, if the threshold values are exceeded by two or more days. In France the moving average of minimum and maximum temperatures of three days is counted.

What concerns Belgium HHWS there should be mentioned that in this country warnings are provided not only by Belgium Meteorological Institute. This institution provides warnings based on minimum and maximum temperature values, which threshold differ according to the region. Other warnings are provided on the basis of the ozone data given by Federal Public Service (FPS) Health, Food Chain Safety and Environment in co-operation with Belgian Interregional Environment Agency and The Royal Meteorological Institute of Belgium,.

More complicated techniques are used in Italy (Synoptic approach (based air mass)) and Germany (perceived temperature - PT). Simple temperature-humidity indices are used in 6 countries: Italy, some cities use Apparent Temperature, Austria and Switzerland - the Heat Index. Malta and Romania have their indices: Malta – Heat stress index, Romania – ITU (temperature humidity index).

Currently in Lithuania "Humidex" heat index forecasts are designed to provide people information about the health risks, but they are not the basis of informing certain services that appropriate action would be taken to reduce the effects of heat. In Lithuania heat is when daily maximum temperature rises more than 30 degrees C and it continues not less than 10 days. Then the extreme situation must be announced. Thou, there have not been such cases during the whole period of the measurements.

In Lithuania it is necessary to update the criterions for heat alerts on the basis of the research. It is also necessary to evaluate the health effects of the previous heat waves. The previous chapter states that the best criterions for the announcement of heat risk are maximum temperature, the complex of maximum and minimum temperatures or “Humidex” index. It is required to choose one of the following criteria and with exception of the risk levels to begin officially inform of the hazards of heat. It is necessary to complete and implement a functioning warning system of the heat impact on public health which could timely inform the residents and particular services of the risk of heat, thereby preventing heat casualties.

Measurements and forecasting of ultraviolet radiation in Lithuania

In Lithuania UVI fluctuates from 1 to 8,5 (according to the measurements of LHMS in period of 2001–2008), and reaches maximum values in June-July months.

Every year German Weather Service performs YVI forecast verifications to different cities of Europe. Though, in different areas verifications are slightly different summarising verifications of 14 European cities shows that approximately half of the provided forecasts were absolutely correct, i.e., the difference was close to 0 UVI. While UVI measured in Kaunas MS is higher than forecasted in even 93 % of cases in 2008. In most of the cases (35 %) measured value is bigger by 2 UVI.

The comparison of ozone and UVI data of year 2001 and 2008, showed that ozone values were similar, while UVI was significantly increased. Measured levels of UV radiations differ in 2 UV index values, similar value was found during verification of UVI forecast. The main reason of these differences could be possible changes of spectral or angular sensitivity, or even of both of them, that is why the measured UVI values are higher.

Calibration the data, i.e., the inclusion of the systematic amendments should be made continually. Various devices have their systemic amendments, it is necessary to take them into account and correct measured values. In Kaunas UV radiation is measured by UV-biometer. Devices of this type have different spectral and angular sensitivity. Therefore, depending on difference between their and CIE spectrum and ideal cosinusoid adequate amendments should be included.

To determine the Kaunas MS data systematic errors, i.e., to calibrate the data, it is necessary to establish the calibration matrix and to calculate it’s constant. Sensible to do so using the data of the beginning the exploitation while it had not lost those qualities, which are indicated by the device manufacturer. The year 2001–2002 were chosen for measurements as it was the beginning of device exploitation.

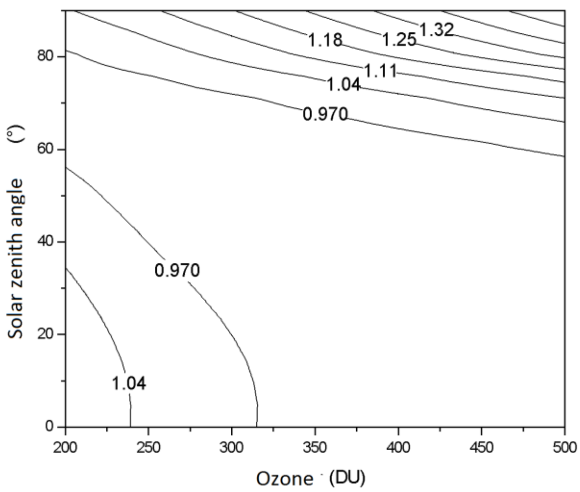

Figure 5. "Real" calibration matrix calculated for the following atmospheric characteristics: O_3 –270 DU, θ_{SUN}<30°, AOD – 0.2, albedo – 3%

"True" values of matrix calibration that will be applied to calibration of erythemal radiation measured in Kaunas MS by Solar Light instrument, fluctuate from 0.9 to 1.55. To assess the amendments that may occur in case of application of the maximum or minimum rather than the average value of spectral sensitivity the deviations between the "true" matrix and calibration matrix were calculated with minimum and maximum spectral sensitivity value. In both cases, the maximum deviation was of 7% when the solar zenith angle was > 80 °, with the ozone concentration of about 500 DU.

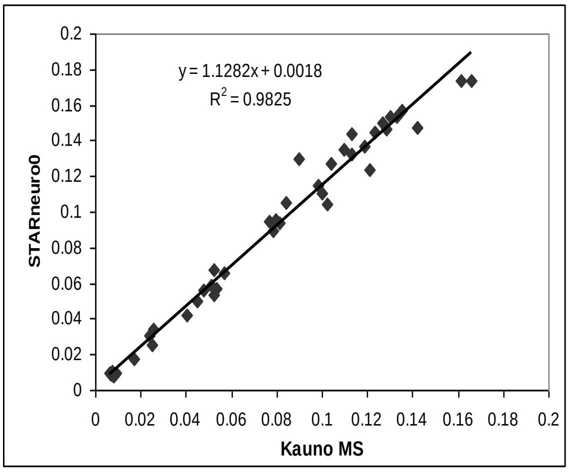

Figure 6. Relation between the calculated (STAR model) and by the calibration matrix multiplied values of maximum intensity erythemal radiation (W/m_2) measured by Kaunas MS in 2001–2002 during cloudless days

General calibration constant is 1.1282 and it is multiplied with all the values measured in Kaunas MS and multiplied with calibration matrix (Fig. 6.). In further research it is compared with simulated data.

This method can be used to calibrate the UV data measured in Kaunas, but it is necessary to perform the calibration of the device and to determine the current values of the spectral and angular sensitivity. Recovery of the totally accurate data is no longer available, but assuming that the device deterioration was gradual the data of quite high-quality reconstructed sequence can be obtained.

In the last chapter maximum daily erythemal radiation data (2001-2002 year) measured and calibrated in Kaunas MS are compared with the calculated by STARneuro model, using the versions STARneuro0 and STARneuro1.

Erythemal radiation simulation on clear days is carried out only with STARneuro0 model, because this version is designed to simulate radiation of clear day. On clear days of the year 2001-2002 the relationship between the measured calibrated radiation and simulated by STARneuro0 model was very strong and statistically reliable, the correlation coefficient - 0.985.

On overcast days there were used versions of models STARneuro0 and STARneuro1. STARneuro0 calculations did not assess the effect of cloud cover, because this version is best to use on a clear day, so dissemination of the data is very high. Model STARneuro1 version calculates the average amount of radiation that reaches the earth's surface on overcast days, because we lack the data on the cloud layers and types. But at the time of measurement of maximum daily erythemal radiation, clouds may be very thin and greater amount of erythemal radiation may reach the surface. In many cases the data calculated by STARneuro1 model remains lower than measured.

On cloudy days when the data on radiation erythemal daily peak values are available, but there are no data on the cloud layers and their thickness STARneuro0 version is more suitable for use. The correlation coefficient between measured data and simulated by STARneuro0 is – 0,973, and by STARneuro1 – 0,775.

STARneuro0 can be used on clear days and on overcast or cloudy days when there are the data of erythemal radiation daily peak values, but there are no specific data on the cloud layers and their thickness.

In order to carry out verification of the UVI index forecast without the former data of UVI on that day STARneuro0 version can be used to calculate the UV levels. Also in those days, when the accuracy of the data is misdoubt, but the weather conditions are known, it is possible to calculate the expected values of UVI. If necessary, the model can be used in forecasting UVI.

Conclusions

1. Results of the sociological survey of Lithuanian population revealed that 55 % of respondents feel little weather impact on their health, while 19 % feel a big impact. Respondents over 65 feel the strongest weather impact on their health. People are more sensitive to changeable weather. It was found that weather changes cause drowsiness, fatigue and joint pain for 35 % respondents.
2. Most cardiovascular diseases show seasonality – in Vilnius the number of cases rises in winter and decreases in summer. The main meteorological indicators, which determine the number of cases, are: the atmospheric pressure and its change, air temperature, air humidity and amount of precipitation.
3. The number of cases of arterial hypertension has the strongest relationship with weather conditions: statistically significant relationships are found with a number of meteorological elements or their complexes. Meteo-sensitive diseases may also include cardiopathy, acute myocardial infarction and paroxysmal tachycardia. Other investigated diseases are less dependent on current meteorological conditions. Most often disease exacerbations are associated with the third weather class – when after a longer period of prevailing anticyclonic weather pressure begins to fall and a big weather change starts; or when there is a predominant eastern transfer in anticyclones and cyclone – ninth weather class.
4. In Lithuania maximum "*Humidex*" index values are usually recorded in late July and early August. Their maximum is in Panevežys where the average index value of five last days of July reaches 26,1 °C. The maximum average difference between the "*Humidex*" values and the measured air temperature is recorded in Klaipeda. Due to higher air humidity here in late July and early August than elsewhere in the country the index values in Klaipeda are an average of 4 °C higher than the measured air temperature.

5. It was found that, on average, 22 % (Klaipeda) and 31 % (Panevezys) of summer days have the maximum "*Humidex*" index value exceeding the discomfort trigger threshold of 27 °C. During the 1993-2006 period there were 32 days in summer, when in one or more of the analyzed Lithuanian cities, the index value exceeded a high health hazard threshold of 37 °C. The absolute maximum of the period of the research - 43,4 ºC - was recorded on 30 July 2002 in Panevėžys.
6. 56 % of cases of high "*Humidex”* 'index values occurred when an anticyclonic ridge formed in the 500 hPa isobaric surface over Lithuania. An upper anticyclone caused such weather in 31 % of the cases, and remaining 13 % were related to high-pressure fields (high-altitude anticyclone periphery). In 56 % of cases extra high index values were recorded in the front periphery of the approaching cyclone. In 28 % of cases such weather resulted from anticyclones and 16 % from a higher-pressure field. In all cases, a coincident thermal ridge was formed in the 850 hPa isobaric surface level and temperature was higher than 15 °C.
7. All over Lithuania the lowest average Wind Chill index values are recorded between the end of December and early January and during January over the last decade. The lowest Wind Chill value in winter, -10.2 °C, was found in Vilnius. In winter months in Lithuania 3-5 °C difference is usually fixed between the measured temperature and wind chill, in rare cases, this difference can exceed even 10 degrees.
8. In all cases analyzed, when the lowest wind chill values were recorded the weather in Lithuania was governed by Arctic anticyclones. At the level of 850 hPa isobaric surface air temperature was below -15 °C. An absolute wind chill minimum for the investigation period, of -38,6 ºC, was recorded on 27 December 1996 in Vilnius. Wind Chill temperatures below dangerous levels of -25 °C occur on average on 0.8 to 3 % of days during the cold season.
9. During the 1993-2007 investigation period 23 periods of heat were identified. There were four years without an occurrence of heat periods, in other years heat periods were found to have occurred one to five times per year. Health effects of heat are felt on the second day of the period, when mortality increases by 15 %. Considering this, heat warnings should be made in cases when high temperatures or high thermal index values are forecasted for two consecutive days. "Humidex"

index, the maximum temperature and a complex of maximum and minimum temperature are the most appropriate indicators to describe the heat risk.

10. After calibration of Kaunas MS measured erythemal radiation data it was found that the "true" calibration matrix values that were applied to calibration of erythemal radiation measured by Kaunas MS Solar Light instrument ranged from 0,9 to 1,55. The general relative correction of calibration linked to the sensitivity of the sensor is 1.1282.
11. It was found that the version of STARneuro0 model is best suited for use on clear days (correlation coefficient - 0.985) compared to overcast (correlation coefficient - 0.982) or cloudy (correlation coefficient - 0.956) days.

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2. **Liukaitytė J.** (2007). Klimato poveikis žmogaus sveikatai. In Bukantis A., Šimkūnas P., Toločkaitė E. (edt.), Klimato kaita: prisitaikymas prie jos poveikio Lietuvos pajūryje.

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7. Nariūnaitė I., **Liukaitytė J.** (2010). Fiziologiškai ekvivalentinės temperatūros (PET) indekso pokyčių vertinimas Lietuvoje 13-osios Lietuvos jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis“, įvykusios Vilniuje 2010 m. 03 mėn. 25 d., medžiaga

Curriculum Vitae

Judita Liukaitytė was born on May 12, 1981, in Marijampolė. In 1999 she graduated from Liudvinavas K. Boruta Secondary school and entered the Faculty of Natural Sciences of Vilnius University. The bachelor studies were finished by the work "STARsci modelling of maximum intensity of erythermal radiation in Kaunas MS in 2001-2002". In 2003 was conferred a degree of bachelor of geography. In 2003–2005 continued the studies at the Department of Hydrology and Climatology of the Faculty of Natural Sciences of Vilnius University. Part of her Master Thesis she prepared in Meteorology Institute of Ludwig-Maximilians-Universität, München. In 2005 defended a thesis for master degree "Application of the STAR model for calibration of erythermal radiation measured at Kaunas meteorological station" and was conferred a master degree of geography (hydrometeorology). In the same year entered doctoral studies at Vilnius University. During the doctoral studies published in 13 scientific articles. Three articles were published in journals included in the international databases. The dissertation results were reported at six international and ten republican conferences. In 2009 participated in trainings in Deutscher Wetterdienst, Human Biometeorology group, where prepared a part of dissertation.

Judita Liukaitytė was worked as a Weather Forecaster at Lithuanian Hydrometeorological Service under the Ministry of Environment. She was engaged in educational activities and supervised students doing researches. Participated in numerous trainings in Lithuania and abroad.

BIOMETEOROLOGINIŲ RODIKLIŲ PRITAIKYMAS LIETUVOJE

Santrauka

Orai veikia visuomenės sveikatą, tačiau dažniausiai pasitaikantys ir daugiausia žmonių aukų pareikalaujantys ekstremalūs gamtiniai reiškiniai. Svarbu laiku informuoti žmones apie artėjančią nelaimę, galimą poveikį sveikatai ir kaip nuo to apsisaugoti. Biometeorologinė informacija suteikia išankstinius perspėjimus apie sveikatai gresiantį pavojų, kaip meteorologinių sąlygų kompleksas veiks žmonių sveikatos būklę ar komfortiškumą. Autorė tikisi savo darbu prisidėti prie platesnio analizuojamos problemos pažinimo ir sukurti pagrindą biometeorologinės informacijos sklaidos ir prognozavimo sistemos Lietuvoje sukūrimui.

Darbo objektas

Lietuvos biometeorologinė aplinka

Darbo tikslas

Nustatyti orų poveikį Lietuvos gyventojų sveikatai ir atlikti biometeorologinių sąlygų šalies teritorijoje vertinimą

Darbo uždaviniai

1. Atlikti Lietuvos gyventojų jautrumo orams sociologinį vertinimą;
2. nustatyti orų sąlygų poveikį širdies-kraujagyslių ligų kartojimuisi Vilniuje;
3. išanalizuoti „Humidex“ ir Vėjo žvarbumo indeksų kaitą Lietuvoje;
4. įvertinti karščio poveikį Vilniaus gyventojų mirtingumui;
5. atlikti Kauno MS išmatuotų ultravioletinės spinduliuotės dydžių kalibraciją;
6. įvertinti modelio STAR tinkamumą ultravioletinės spinduliuotės intensyvumo Lietuvoje prognozei.

Ginami teiginiai

1. Orų sąlygos ir jų pokyčiai veikia visuomenės sveikatos būklę Lietuvoje. Susirgimų širdies-kraujagyslių ligomis skaičius priklauso nuo orų sąlygų ir gali būti prognozuojamas remiantis ryšiais su meteorologiniais rodikliais.
2. Terminiai indeksai teikia svarbią papildomą informaciją apie teritorijos biometeorologines sąlygas. Biometeorologiniam šalčio poveikiui prognozuoti tinka Vėjo žvarbumo indeksas, karščio poveikiui – „Humidex“ indeksas.

3. Gyventojų mirtingumas padidėja karščio bangų metu. Todėl būtina karščio poveikio visuomenės sveikatai perspėjimo sistema.

4. STAR modelis yra tinkamas atlikti ultravioletinės spinduliuotės duomenų kalibraciją ir gali būti panaudotas UV spinduliuotės intensyvumo skaičiavimui ir prognozavimui Lietuvoje.

Darbo naujumas

Šiame darbe pirmą kartą Lietuvoje: 1) vykdyta orų sąlygų poveikio visuomenės sveikatai sociologinė apklausa; 2) įvertintas meteorologinių sąlygų poveikis sergantiems širdies-kraujagyslių ligomis Vilniuje; 3) išanalizuota terminių indeksų kaita laike ir erdvėje; 4) įvertintas karščio poveikis žmonių mirtingumui Vilniaus mieste; 5) įvertintas įvairių biometeorologinių karščio indikatorių panaudojimo gyventojų perspėjimui apie karščius tinkamumas; 6) įvertintas STAR modelio tinkamumas UV spinduliuotės Lietuvoje prognozei.

Darbo aktualumas ir pritaikomumas

Didėjant supratimui apie klimato ir orų poveikį žmogui, šiai sričiai vis daugiau dėmesio yra skiriama ir nacionalinėse orų tarnybose. Daugelis jų teikia informaciją ir prognozes, kaip prisitaikyti prie nepalankių sveikatai meteorologinių sąlygų ir sumažinti aplinkos poveikį bei keliamą stresą. Darbe aptariami prognozavimo metodai gali būti naudojami Lietuvos hidrometeorologijos tarnyboje prie Aplinkos ministerijos biometeorologinėms prognozėms sudaryti. Atlikti tyrimai padės plėtoti kurortologijos ir visuomenės sveikatos sritis. Remiantis šiuo darbu, galima tobulinti egzistuojančią išankstinių perspėjimų apie stichinius, katastrofinius ir kitus pavojingus hidrometeorologinius reiškinius sistemą. Taip pat galima kurti karščio poveikio visuomenės sveikatai perspėjimų sistemą, informuojančią apie karščio poveikį sveikatai. Tai indėlis ir į klimato kaitos poveikio žmogaus sveikatai tyrimus, ir gali būti naudojamas tobulinti prisitaikymo prie klimato kaitos strategiją.

Darbo rezultatai

Medicininės-meteorologinės prognozės svarbiausios žmonėms, kurie jaučia didelį orų daromą poveikį sveikatai. Ypač šios prognozės svarbios vyresniems kaip 60 metų amžiaus žmonėms, nes kas trečiam iš jų pasireiškia stiprus poveikis sveikatai. Lietuvos gyventojai mano esą jautrūs ir atskirų meteorologinių elementų pokyčiams, ir viso elementų komplekso pasikeitimams. Lietuviai jautriausi besikeičiantiems orams, kai šie būna drėgni, šaltėja, šiltėja ar būna audringi. Apklausos rezultatai yra labai artimi gautiems Vokietijoje. Daugelis apklaustųjų laiko reikalingomis prognozes, kurios informuotų apie orų poveikį sveikatai, taip pat norėtų gauti informaciją apie oro užterštumą ir UV spinduliuotę.

Norint pradėti skelbti medicinines-meteorologines prognozes, prieš tai būtina nustatyti ligų kartojimosi dažnumo priklausomybę nuo meteorologinių veiksnių Lietuvoje. Darbe analizuota 11 širdies ir kraujagyslių ligų pasiskirstymas per metus ir priklausomybė nuo meteorologinių elementų ar jų kompleksų. Vilniuje 2007-2008 metais daugiausia užfiksuota arterinės hipertenzijos, nestabilios krūtinės anginos ir insulto atvejų (>5000). Širdies bei kraujagyslių ligos turi aiškią metinę eigą – ligų pikas šaltuoju metų laikotarpiu, o sumažėjimas – šiltuoju. Meteorologiniai parametrai statistiškai reikšmingai siejasi ne su visomis širdies ir kraujagyslių ligomis. Tačiau daugelis ligų yra meteotropinės ir susirgimų skaičius statistiškai reikšmingai padidėja esant nepalankioms meteorologinių elementų reikšmėms. Pagrindinis meteorologinis elementas, su kuriuo siejasi greitosios pagalbos iškvietimai, yra vidutinė paros temperatūra, rasti statistiškai patikimi ryšiai su 5 ligomis: arterine hipertenzija, kardiopatija, ūmiu miokardo infarktu, širdies veiklos nepakankamumu ir paroksizmine tachikardija. Kitas svarbus rodiklis, su kuriuo galima sieti atsirandančius negalavimus, yra atmosferos slėgis. Statistiškai patikimi ryšiai gauti su ūminiu miokardo infarktu, širdies laidumo sutrikimais, paroksizmine tachikardija ir prieširdžių virpėjimu bei plazdėjimu. Tyrimo metu buvo nustatyta, jog iškvietimų skaičius išauga artėjant didesnes orų permainas nešančiam ciklonui.

Darbe įvertintas karščio ir šalčio keliamo terminio diskomforto dydis Lietuvos teritorijoje, atliktas „Humidex“ indekso reikšmių dinamikos vasaros metu, o „Vėjo žvarbumo“ šaltuoju metų laiku vertinimas, nustatyti teritoriniai skirtumai, įvertinta rodiklio paros eiga. Be to, darbe vertinamos sinoptinės sąlygos, lemiančios ekstremalius indeksų dydžius.

Skirtumas tarp „Humidex“ indekso dydžio ir išmatuotos temperatūros tiriamojo laikotarpio vasaros mėnesiais didžiuosiuose Lietuvos miestuose dažniausiai nėra didelis. Vilniuje modalinis intervalas 1–2, Kaune ir Klaipėdoje 2–3 °C. Klaipėdoje ir daug dažniau nei kitose vietovėse skirtumas viršija 4 °C (>15 % atvejų). Tai sietina su žymiai didesnėmis oro drėgnumo reikšmėmis pajūryje dienos metu. Retais atvejais šis skirtumas gali viršyti ir 8 laipsnius. Vilniuje užfiksuota daugiausia atvejų (14,2 %), kai indekso reikšmė sutapo su oro temperatūra. Tokių atvejų daugiausia buvo vasaros pradžioje ir pabaigoje. Pajūryje drėgmės kiekis yra didesnis, todėl Klaipėdoje vos 3,2 % atvejų jutiminė temperatūra vasaros dienomis neviršijo išmatuotos.

„Humidex“ indekso reikšmių paros eiga yra labai panaši į oro temperatūros. Maksimali vidutinė indekso reikšmė matavimo terminais fiksuojama 15 valandą ir kinta nuo 21,6 ºC (Klaipėdoje) iki 22,7 ºC (Panevėžyje). Vidutinis skirtumas tarp indekso reikšmės ir oro temperatūros kinta nuo 1,8 ºC (6 val.) iki 2,4 ºC (21 val.). Dažniausiai didelis analizuojamų temperatūros reikšmių skirtumas visoje Lietuvoje buvo fiksuojamas šiltojo fronto uţnugaryje plūstelėjus karštam ir drėgnam tropiniam orui.

Skirtumas tarp vėjo žvarbumo ir išmatuotos temperatūros tiriamojo laikotarpio žiemos mėnesiais Vilniuje dažniausiai yra -3...-4 ºC, Kaune ir Klaipėdoje -4...-5 °C. Retais atvejais šis skirtumas gali viršyti ir 10 laipsnių. Atvejų, kai vėjo žvarbumo ir išmatuotos temperatūrų skirtumas viršijo 10 laipsnių, Vilniuje užfiksuota 10, Kaune – 29, Klaipėdoje pasitaikė net 41 atvejis. Pagrindinis komponentas, turintis poveikio atsirasti tokiems skirtumams, yra stiprus vėjas. Šaltasis sezonas Lietuvoje pasižymi aktyvia ciklonine veikla, o didžiausi skirtumai užfiksuoti tada, kai orus lėmė ciklono užnugaris. Tuomet į Lietuvą ima plūsti šaltas oras ir pučia stipriausi vėjai.

Kuriant karščio poveikio visuomenės sveikatai perspėjimų (KPVSP) sistemą dažniausiai naudojami mirtingumo duomenys. Jie siejami su oro temperatūra ar kitais karščio poveikį sveikatai nusakančiais indikatoriais. Norint įvertinti karščio poveikį mirtingumui Vilniuje buvo išskirti karščio periodai pagal 6 karščio indikatorius: minimalią, maksimalią ir vidutinę temperatūrą, HI, PET ir „Humidex“ indeksus.

Karščio poveikis pasireiškia jau antrąją karščio bangos dieną, tuo metu pasireiškia pirmas mirtingumo pikas, mirčių skaičius išauga 15 %. Vėliau mirtingumas išlieka didesnis už tikėtiną, o antrasis pikas jau 7 dieną iš eilės besitęsiant karščiui, mirčių skaičius išauga 24 %. Po karščio bangos sekančių dviejų dienų metu mirtingumas mažėja, antrąją jis jau tampa mažesnis už tikėtiną mirtingumą. Remiantis tuo galima teigti, kad jei karštis tęsiasi bent dvi dienas, yra būtina skelbti karščio pavojų, nes kyla pavojus sveikatai.

Darbe pateikiama informacija apie 2009 metais veikusias karščio perspėjimo sistemas Europoje. Tuo metu jau 30 Europos šalių skelbė karščio perspėjimus. Maksimali temperatūra yra pagrindinis indikatorius, kuriuo remiantis karščio perspėjimai pateikiami daugumoje šalių. Dar naudojama vidutinė temperatūra, maksimalios ir minimalios temperatūros kompleksas, paprastieji temperatūros-drėgmės indeksai, kaip „Humidex“ prognozuojami 6 šalyse, dvi šalys naudoja kompleksinius indeksus.

Skirtingai nei ankstesnės darbo dalys, paskutinė disertacijos dalis nėra skirta biometeorologinio prognozavimo pagrindimui. Lietuvoje naudojamos Vokietijos meteorologijos tarnybos pateikiamos nemokamos UVI prognozės. Dėl UV matuojančių prietaisų spektrinio jautrumo ir kampinio jutiklio jautrumo paklaidų išmatuoti duomenys skiriasi nuo prognozuotų, todėl sunku juos ir tarpusavyje palyginti, atlikti prognozės verifikaciją. Tam yra reikalinga duomenų kalibracija, t. y. sisteminių paklaidų nustatymas. Lietuvoje tinkamas naudoti kalibracijos metodas aprašomas šioje darbo dalyje, palyginami išmatuoti ir apskaičiuoti dydžiai.

Norint nustatyti Kauno MS duomenų sistemines paklaidas, t. y. kalibruoti duomenis, būtina sudaryti kalibracijos matricą ir apskaičiuoti jos konstantą. Tikslingiausia tai atlikti panaudojus prietaiso eksploatacijos pradžios duomenis. Skaičiavimams pasirinkti 2001–2002, prietaiso eksploatacijos pradžios metai.

Norint atlikti UVI indekso prognozės verifikaciją neturint duomenų apie tądien buvusį UVI galima naudoti STARneuro0 versija apskaičiuotus UV kiekius. Taip pat ir tomis dienomis, kai abejojama duomenų tikslumu, bet žinomos meteorologinės sąlygos, galima apskaičiuoti tikėtinas UVI reikšmes. Esant būtinybei, modelis gali būti naudojamas ir UVI prognozavimui.

Išvados

1. Atlikus Lietuvos gyventojų sociologinę apklausą paaiškėjo, jog 55 % apklaustųjų orai daro nedidelį poveikį sveikatai, o 19 % – didelį. Didžiausią poveikį jaučia vyresni nei 60 metų šalies gyventojai. Labiausiai savijautą veikia besikeičiantys orai. Nustatyta, kad net 35 % respondentų orų pokyčiai sukelia mieguistumą, nuovargį ir sąnarių skausmą.

2. Dauguma širdies ir kraujagyslių ligų yra sezoniškos – susirgimų Vilniuje skaičius išauga žiemą, o sumažėja vasarą. Svarbiausi meteorologiniai rodikliai, nuo kurių

priklauso susirgimų skaičius, yra oro temperatūra, oro drėgnumas, atmosferos slėgis bei jo kaita ir kritulių kiekis.

3. Arterinės hipertenzijos atvejų skaičius geriausiai siejasi su orų sąlygomis: statistiškai reikšmingi ryšiai nustatyti su daugeliu meteorologinių elementų ar jų kompleksais. Prie meteojautrių ligų taip pat galima priskirti kardiopatiją, ūminį miokardo infarktą, paroksizminę tachikardiją. Kitos tirtos ligos mažiau priklauso nuo esamų meteorologinių sąlygų. Dažniausiai ligų paūmėjimai siejami su 3 orų klase – kai po ilgesnį laiką vyravusių anticikloninių orų slėgis ima kristi ir artėja didesnės orų permainos arba esant 9 klasės orams – vyraujant rytų pernašai anticiklone ir ciklone.

4. Didžiausios „Humidex“ indekso reikšmės Lietuvos teritorijoje fiksuojamos liepos pabaigoje ir rugpjūčio pradžioje. Maksimalios jos Panevėžyje, kur paskutinį liepos penkiadienį vidutinė maksimali indekso reikšmė siekia 26,1 °C. Didžiausias vidutinis skirtumas tarp „Humidex“ indekso reikšmių ir išmatuotos oro temperatūros užfiksuotas Klaipėdoje. Liepos pabaigoje ir rugpjūčio pradžioje dėl didesnio nei likusioje šalies dalyje oro drėgnumo indekso reikšmės Klaipėdoje yra vidutiniškai 4 °C aukštesnės nei išmatuota oro temperatūra.

5. Nustatyta, jog dienos, kurių metu maksimalios „Humidex“ indekso reikšmės viršija diskomfortą sukeliančią 27 °C ribą, vidutiniškai sudaro nuo 22 % (Klaipėdoje) iki 31 % (Panevėžyje) bendro vasaros dienų skaičiaus. Tiriamuoju 1993–2006 metų laikotarpiu buvo 32 vasaros dienos, kai viename ar keliuose analizuojamuose Lietuvos miestuose indekso reikšmės viršijo didelį pavojų sveikatai keliančią 37 °C ribą. Absoliutus tiriamojo laikotarpio maksimumas užfiksuotas 2002 metų liepos 30 dieną Panevėžyje – 43,4 ºC.

6. 56 % atvejų aukštos „Humidex“ indekso reikšmės nustatytos tada, kai 500 hPa izobariniame paviršiuje virš Lietuvos susidarydavo aukštuminio anticiklono gūbrys. Aukštuminis anticiklonas tokius orus lėmė 31% atvejų, o likusieji 13 % siejami su aukšto slėgio lauku (aukštuminio anticiklono periferija). Priežeminiame lauke net 56 % atvejų ypač aukštos indekso reikšmės buvo fiksuojamos priešakinėje artėjančio ciklono periferijoje. 28 % atvejų tokius orus lėmė anticiklonas ir 16 % – aukštesnio slėgio laukas. Tuo metu 850 hPa izobarinio paviršiaus lygyje buvo susiformavęs šilumos gūbrys. Temperatūra šiame lygyje visais atvejais buvo aukštesnė nei 15 °C.

7. Žemiausios vidutinės Vėjo žvarbumo indekso reikšmės visoje Lietuvoje fiksuojamos nuo gruodžio pabaigos iki sausio pradžios ir sausio paskutinę dekadą. Žemiausia vėjo žvarbumo reikšmė žiemą nustatyta Vilniuje, -10,2 °C. Tarp išmatuotos temperatūros ir vėjo žvarbumo dažniausiai žiemos mėnesiais Lietuvoje fiksuotas 3–5 °C skirtumas, retais atvejai šis skirtumas gali viršyti ir 10 laipsnių.

8. Visais analizuojamais atvejais, kai buvo fiksuotos žemiausios vėjo žvarbumo reikšmės, Lietuvos orus lėmė Arkties anticiklonai. 850 hPa izobarinio paviršiaus lygyje oro temperatūra būdavo žemesnė nei -15 ºC. Absoliutus tiriamojo laikotarpio vėjo žvarbumo minimumas užfiksuotas 1996 metų gruodžio 27 d Vilniuje, -38,6 ºC. Vėjo žvarbumo temperatūra žemiau pavojingos ribos -25 ºC ribos pasitaiko vidutiniškai 0,8–3 % nuo bendro šaltojo sezono dienų skaičiaus.

9. Tiriamuoju 1993-2007 metų laikotarpiu buvo išskirti 23 karščio laikotarpiai. Ketverius metus karščio periodų nepasitaikė, o kitais tiriamo laikotarpio metais karščiai buvo nustatomi nuo 1 iki 5 kartų per metus. Karščio poveikis sveikatai pasireiškia jau antrąją laikotarpio dieną, kai mirtingumas padidėja 15 %. Dėl to karščio perspėjimai turėtų būti sudaromi tais atvejais, jei dviem dienom iš eilės prognozuojama aukšta temperatūra ar didelės terminių indeksų reikšmės. „Humidex" indeksas, maksimali temperatūra ir maksimalios bei minimalios temperatūros kompleksas yra tinkamiausi indikatoriai karščio pavojui nusakyti.

10. Atlikus Kauno MS išmatuotų eriteminės spinduliuotės duomenų kalibraciją, nustatyta, jog „tikrosios" kalibracijos matricos reikšmės, kurios buvo taikomos Kauno MS Solar Light instrumentu išmatuotai eriteminei spinduliuotei kalibruoti, svyruoja nuo 0,9 iki 1,55. O bendroji kalibracijos su jutiklio jautrumu susieta santykinė pataisa yra 1,1282.

11. Nustatyta, jog STARneuro0 modelio versija geriausiai tinka naudoti tiek giedromis dienomis (koreliacijos koeficientas – 0,985), tiek apsiniaukusiomis (koreliacijos koeficientas – 0,982) ir debesuotomis (koreliacijos koeficientas – 0,956) dienomis. Ji tinkama naudoti atliekant UVI indekso prognozės verifikaciją ar prognozuojant UVI.

Curriculum vitae

Judita Liukaitytė gimė 1981 metų gegužės 12 dieną Marijampolėje. 1999 metais baigė Liudvinavo K. Borutos vidurinę mokykla ir įstojo į Vilniaus universiteto Gamtos mokslų fakultetą. Bakalauro studijas baigė darbu „Eriteminės radiacijos prietakos Kaune 2001 – 2002 metais modeliavimas STARsci modeliu". 2003 metais jai buvo suteiktas geografijos bakalauro laipsnis. Nuo 2003 iki 2005 metų tęsė studijas Vilniaus universiteto Gamtos mokslų fakulteto Hidrologijos ir klimatologijos katedroje. Dalį magistrinio darbo ji paruošė Miuncheno L.Maximilians universiteto Meteorologijos institute. 2005 metais Judita Liukaitytė apgynė magistro darbą "Kauno MS išmatuotos eriteminės radiacijos rodiklių kalibracija bei jų palyginimas su STAR modeliu apskaičiuotais dydžiais" ir įgijo geografijos mokslų (hidrometeorologijos krypties) magistro kvalifikacinį laipsnį. Tais pačiais metais Judita Liukaitytė įstojo į Vilniaus universiteto geografijos krypties doktorantūros studijas. Per studijų laiką disertacinio darbo tema paskelbti 3 straipsniai referuojamuose mokslo žurnaluose, 7 straipsniai recenzuojamuose ir 3 nerecenzuojamuose leidiniuose. Taip pat darbo rezultatai buvo pristatyti 6 tarptautiniuose ir 10 respublikinių mokslinių renginių. 2009 metais atliko šešių mėnesių stažuotę Vokietijos meteorologijos tarnyboje, kur buvo ruošta dalis disertacijos darbo.

Judita Liukaitytė dirbo sinoptike Lietuvos hidrometeorologijos tarnyboje prie Aplinkos ministerijos. Vykdė pedagoginę veiklą, vadovavo studentų moksliniams darbams. Dalyvavo daugelyje Lietuvoje ir kitose šalyse vykdomų mokymų.