Public health vulnerability to heat-related impacts of climate change in Cyprus

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Abstract

This study investigates the heat-related impacts of climate change on public health in Cyprus. Most of the health problems in Cyprus and in the Mediterranean generally, are related mainly to the warming already occurred as well as to extreme weather events such as heatwaves. In addition projections indicate that warming and extreme events will increase in future posing serious threats on human health. For the investigation of the relationship bretween hot weather condition and mortality in Cyprus, a statistical model was constructed showing linear increase of mortality with increasing temperature. Humidex is also calculated, using outputs from several regional climate models. The analysis revealed a significant increase in the Humidex in future period mainly during summer months.

Keywords: Climate change, Human Health, HUMIDEX, Heatwaves, Mortality

Introduction

One of the major concerns of climate change is its impact on human health. The fourth IPCC assessment report provides evidence that climate change currently contributes to the global burden of disease and premature deaths. In fact, it plays an important role in the spatial and temporal distribution of some of the most deadly infectious diseases such as malaria, dengue, tick-borne diseases etc. It is also affecting the seasonal distribution and concentrations of some allergenic pollen species and it has increased heat-related as well as extreme-weather-related morbidity and mortality. The greatest health impacts however, are and will be felt in low income countries, and among the urban poor, the elderly and children in all countries [2].

Mediterranean Basin is already experiencing some of the impacts of climate change on public health. Most of the health problems in the Mediterranean Basin and in Cyprus are related mainly to the warming already occurred as well as to extreme weather events such as heatwaves, floods, fires etc. From the 1960's until today, the intensity, duration and number of heat wave events in the Eastern Mediterranean where Cyprus is located have increased by 7,6 ± 1,3, 7,5 ± 1,3 and 6,2 ± 1,1 respectively posing serious threats to human health [8]. Observations in the various Mediterranean countries showed that the percentage increase of mortality associated with 1 degree increase of apparent temperature ranged from 0.1% to 8.0% [11]. Concerning heatwaves, the increase in mortality is high: total deaths from natural causes increased by 14%, deaths from cardiovascular problems by 22% and respiratory problems by 32% during heatwaves events [11]. In Cyprus, examples are the heat waves that hit the island in 1998 (August), 2000 (July) and 2007 (July) which caused the death of 52, 5 and 4 people respectively [4, 5].

The projected climate warming in Cyprus (Table 1), in other words, the increase in air temperature as well as the increase in the frequency and intensity of extreme weather events especially during summer has a negative effect on public health. To investigate such impacts of projected climate warming on the public health in Cyprus a statistical model for heat stress which combine excessive heat and mortality was constructed while the humidity index – Humidex, a parameter employed to express the temperature perceived by people, has also been examined.

Table 1: Near future climate warming in Cyprus related to present-day climate (Future – control period).

	Western Regions	Mountain Regions	Inland Regions	Southern Regions	Southeastern Regions
TXa	(+) 1.4	(+) 1.9	(+) 1.6	(+) 1.5	(+) 1.3
TXDJF	(+) 1.2	(+) 1.2	(+) 0.8	(+) 1.2	(+) 0.7
TXMAM	(+) 1.5	(+) 1.7	(+) 1.6	(+) 1.5	(+) 1.4
TXJJA	(+) 1.6	(+) 2.6	(+) 2.5	(+) 2.0	(+) 1.8
TXSON	(+) 1.4	(+) 1.9	(+) 1.5	(+) 1.7	(+) 1.3
TX>35°C	(+) 2	(+) 30	(+) 34	(+) 19	(+) 17
TN>20°C	(+) 32	(+) 38	(+) 29	(+) 30	(+) 25
The (+) indicates increases					

where: TXa=Average annual maximum temperature (Tmax), TXDJF=Average winter Tmax, TXMAM=Average spring Tmax, TXJJA=Average summer Tmax, TXSON=Average autumn Tmax, TX>35°C=Number of heatwave days (maximum temperature>35°C), TN>20°C= Number of tropical nights (minimum temperature>20°C). Projections carried out by the Hadley Centre PRECIS RCM in the framework of European Union project CYPADAPT (http://uest.ntua.gr/cypadapt/)

Deaths and health problems related to heat waves and high temperatures

Excessive heat is a well-known cause of heat stress, exacerbated illness and mortality. Heatwaves have readily discernible health outcomes because they result in a large number of deaths and affect relatively large, heterogeneous areas simultaneously. However, not all heat waves have a similar impact on mortality. In addition to the intensity of a heat wave, the duration and the timing of the event are particularly important. Illnesses recognizable as the direct results of exposure to prolonged periods of high environmental temperature are heatstroke, heat exhaustion, and heat cramps.

To investigate the relationship between hot weather conditions and mortality, empirical-statistical models for heat stress were constructed for the island of Cyprus during summer (June-August). All-cause daily mortality data for the island of Cyprus, for the period 2004-2011, were acquired from the Cyprus Statistical Service (Department of health statistics), whereas daily maximum temperature data for Nicosia were provided by the Cyprus Meteorological Service for the same time period. We considered Nicosia to be representative of hot weather conditions prevailing in the island during summer.

A time series plot of the all-cause daily mortality for the island Cyprus, covering the period from 2004 to 2011, together with the 30-days running mean (light blue line), and the daily maximum air temperature for Nicosia, are given in Figure 1. Figure 1 shows a clear seasonal variation of mortality: higher in winter and in summer, lower during transient seasons. This is most noticeable in the smoothed 30-days running mean line. It is also apparent that there have been considerable heat or cold related deaths in Cyprus.

An empirical-statistical model for heat stress is then constructed for Cyprus, for the summer months (June-August) of the common data period 2004-2011. Heat-related deaths are defined as the number of deaths occurring in excess of the number that would have been expected for that population in the absence of stressful weather. For the calculation of excess deaths, i.e. deaths beyond those expected for a specific period in a specific population, we have used the fixed mean of daily mortality for each summermonth, for the period 2004-2011 (12.9 deaths in June, 13.4 in July and 13.6 in August). Daily excess deaths were then calculated by subtracting the expected (fixed mean) from the observed daily death values [3]. For example, that meant subtracting 12.9 from every observed daily death for June, 13.4 from every observed daily death of July, and 13.6 from every observed daily death of August. Each number of excess deaths was then grouped into the corresponding 1°C interval of maximum air temperature. For example, if on a particular day, the maximum temperature was 39.3°C and there were 10 excess deaths, 10 would be put in the 39-39.9°C interval. All excess deaths in each 1°C interval for the entire period were added in order to find out where heat-related deaths were no longer detectable. In this way only temperatures over a certain threshold were regressed. This level of aggregation was necessary because no statistically significant relationship could be established when each excess death was plotted against its corresponding maximum air temperature. For example, if the maximum temperature on the interval 39-39.9°C was observed 5 times, and the calculated excess deaths were: +20, -15, +12, -7 and +10, then the SUM = (+20) + (-15) + (+12) + (-7) + (+10) = 20. Finally, the sum of the excess deaths in each interval was divided by the frequency of occurrence of that temperature interval in the 2004-2011 period, to give the number of deaths per day for a particular temperature interval. For example, if there were 681 deaths (the sum of all excess deaths) in the 39°C interval (i.e. 39-39.9°C), and the number of times this temperature interval was observed in the period 2004-2011 was 27, then the number of excess deaths per day would be equal to 681/27=25.2.

Following the methodology given above, the calculated summer excess deaths (or the heat-related mortality) per day for each maximum air temperature interval, for Cyprus during the period 2004-2011, are presented in Figure 2. The frequency of occurrence of the temperature intervals during this period examined is also included, indicating the percentage of days in a year that this temperature interval occurs. For example a 0.15 frequency of temperature interval of 38°C means that 15% of the days in the examined period (about 101 days out of a total 684 days) will experience temperatures between 38°C and 38.9°C.

A fairly linear increase of mortality with increasing temperature and thus high sensitivity is observed - with hotter days associated with greater morality risk. Heat-related deaths start to be discernible when the maximum temperature is 38°C or above.

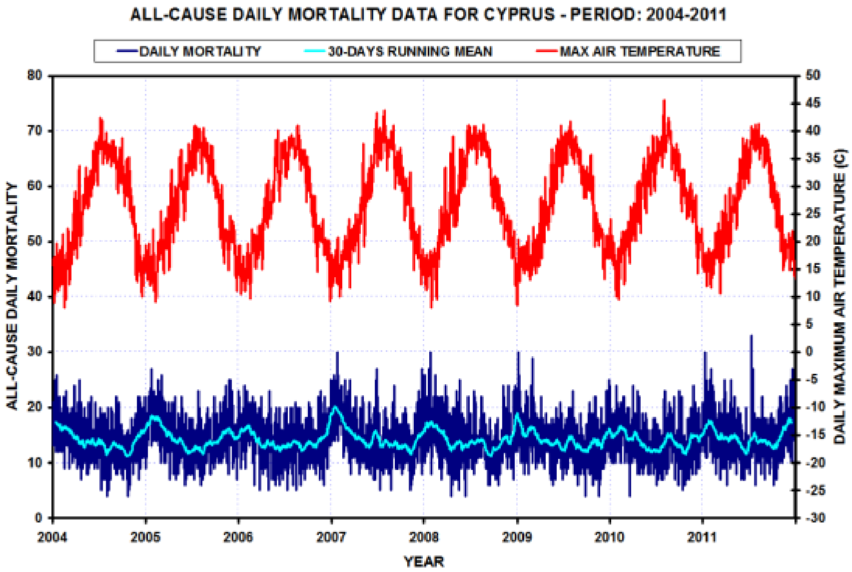

Figure 1: All-cause daily mortality data for Cyprus (blue line, left-hand axis) and daily maximum air temperature (red line, right-hand axis) for the period 2004-2011. The light blue line represents the smoothed 30-day running mean.

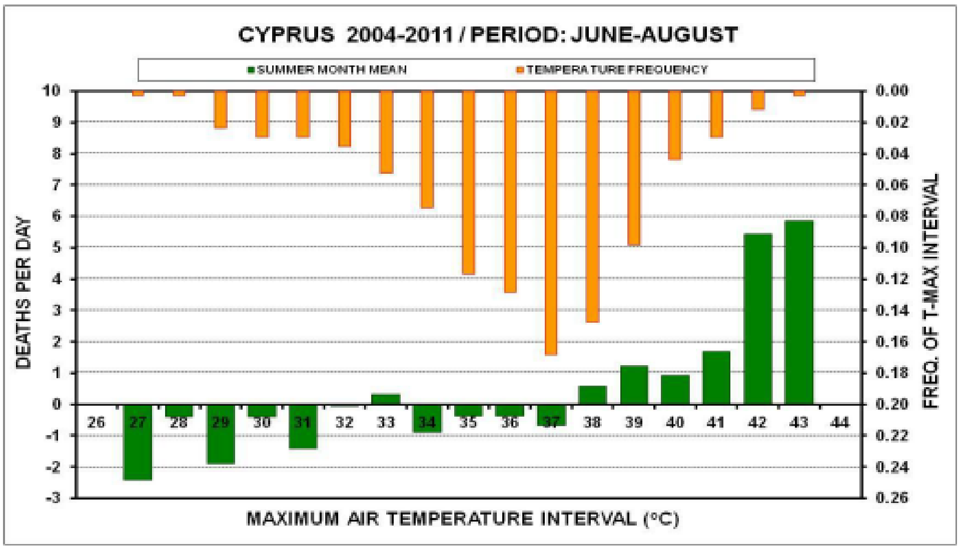

Figure 2: Daily excess summer deaths (green bars, left-hand axis) in Cyprus by maximum air temperature interval for the years 2004-2011. The frequency of occurrence of each temperature interval (right-hand axis) is shown using orange bars.

Humidex

To further examine the potential negative impacts of climate warming on human life in Cyprus, the humidity index (Humidex) [9] - a parameter employed to express the temperature perceived by people - has also been examined.

Humidex is applied in summer and generally warm periods and describes the temperature felt by an individual exposed to heat and humidity. More specifically, the Humidex parameter (in °C) is calculated by the following equation:

$$T\,(h) = Tmax\, + \,{}^{5}\!/_{9} \times (e - 10)\,,$$

Where *e* is the vapour pressure:

$$e = 6.112\, \times 10^{\left(7.5\, \times \, ^{Tmax}/_{(237.7\, + Tmax)}\right)} \times \, ^{h}/_{100}$$

Tmax is the maximum 2m air temperature (°C) and *h* is the humidity (%).

Furthermore, 6 classes of Humidex ranges are established to inform the general public for discomfort conditions:

<29°C comfortable
30–34°C some discomfort
35–39°C discomfort; avoid intense exertion
40–45°C great discomfort; avoid exertion
46–53°C significant danger; avoid any activity
>54°C imminent danger; heart stroke.

All calculations were performed using PRECIS (Providing Regional Climates for Impact Studies) regional Climate Model based on the United Kingdom (UK) Meteorological Office Hadley Centre HadRM3P model [6, 7]. In addition, six RCMs of the ENSEMBLES project have also been used namely KNMI, METNO, CNRM, METO, C4I and MPI. The results of models were used as an ensemble mean for testing and comparing the respective results of PRECIS. In all simulations the period 1961–1990 used as the base period (control run) and is used here as reference for comparison with future projections for the period 2021–2050. The future period simulations of the model are based on the IPCC SRES A1B scenario [10]. The A1B scenario provides a good mid-line scenario for carbon dioxide emissions and economic growth [1]. The future period has been chosen specifically for the needs of stakeholders and policy makers to assist their planning in the near future, instead of the end of the twenty-first century as frequently used in other climate impact studies.

Results

At first, Figures 3a and 3b illustrate the average summer Humidex for the control period as calculated by PRECIS and Ensemble model mean respectively. In inland (Nicosia) and southeastern (Larnaca) regions, Humidex varies from 40 to 42°C revealing great discomfort conditions for people. Less discomfort is presented in mountain regions of Troodos as well as in southern and western parts of Cyprus since Humidex reaches approximately 36 - 37°C (Fig. 3a) or 37 - 38°C (Fig. 3b). As far as future changes are concerned, a significant increase in Humidex of about 3.5 – 4°C is projected (PRECIS – Fig. 3c) for all the domain of study. This means that significant danger conditions are anticipated mainly for inland regions where Humidex is projected to reach approximately 47°C. Regarding Ensemble model mean projections (Fig. 3d), an increase in the Humidex of about 3 – 3.5°C is anticipated for the domain of study reaching almost 46°C i.e. significant danger conditions according to classification.

To examine the potential influence of the anticipating warming of late spring and early autumn periods on the human comfort or discomfort, the average spring Humidex and the average fall Humidex have also been studied. Regarding spring, both Figures 4a (PRECIS) and 4b (Ensemble model mean) illustrate that in the present-day climate, Humidex varies below 29°C (20 – 25°C) revealing comfortable conditions for residents. As regards near future changes, a slight increase in Humidex of about 2 – 2.5°C is projected by both PRECIS (Fig. 4c) and Ensemble model mean (Fig. 4d) for the domain of study. This increase is not expected to influence comfortable conditions according to the classification.

Autumn, in contrast with spring, presents higher Humidex as Figures 5a and 5b are shown. In particular, inland and southeastern regions show the higher Humidex of about 31°C in case of PRECIS (Fig. 5a) and 32°C in case of Ensemble model mean (Fig. 5b) testifying some discomfort for people. Mountain, southern and western regions show the lower Humidex varying from 27 – 28°C in case of PRESIS and 28 – 30°C in case of Ensemble model mean. Regarding future changes, both PRECIS (Fig. 5c) and Ensemble model mean (Fig. 5d) project a slight increase in Humidex of around 2.5°C in all the domain of study. Future projections show that the foreseeing atmosphere warming during autumn will create a slight discomfort to residents mainly in inland and southeastern regions.

As for the annual pattern of Humidex, Figures 6a (PRECIS) and 6b (Ensemble model mean) present a similar distribution to seasonal, namely higher Humidex in inland and southeastern regions and lesser in southern, western and mountain regions. More specifically, in inland and southeastern regions annual Humidex varies around 26-28°C while in southern, western and mountain regions varies around 24-26°C. In both cases, Humidex is classified as “comfortable” for the residents. As regards future changes, either PRECIS (Fig. 6c) or Ensemble model mean (Fig. 6d) projects a slight increase in Humidex varying between 2-2.5°C for the domain of study. Similarly with the respective results of present-day climate, near future annual Humidex is classified as “comfortable”.

Apart from seasonal and annual distributions of Humidex, three additional important parameters have also been examined i.e. the number of days with Humidex > 38°C (high discomfort), the number of days with Humidex > 40°C (great discomfort) and the maximum length of Humidex > 38°C (consecutive days with high discomfort). Figures 7a and 7b depict that in the present-day climate there are approximately 90 days with Humidex > 38°C in inland and southeastern regions while in southern, western and mountain regions there are approximately 45 days in case of PRECIS (Fig. 7a) and 60 in case of Ensemble model mean (Fig. 7b). Regarding future changes, PRECIS projects an important increase of about 40 – 42 days in mountain, southern and western regions. In contrast, southeastern and inland regions present a smaller increase of the order of 33 days (Fig. 7c). On the other hand, Ensemble model mean projects a more uniform increase in relation to PRECIS for the domain of study. In particular, the increase is about 32 days in mountain and southern regions and around 28 – 29 days in western, inland and southeastern regions (Fig. 7d).

As regards the number of days with great discomfort for people, in other words with Humidex > 40°C, Figures 8a and 8b illustrate that, inland and southeastern parts present the higher number of days of about 70 while mountain, southern and western parts show approximately 20-25 days in case of PRECIS (Fig. 8a) and 40-45 days in case of Ensemble model mean (Fig. 8b). Concerning near future changes, PRECIS RCM projects an important increase of about 40-43 days in the wider area of the southeastern part of Troodos Mountain as well as in the coast area between Larnaca and Nicosia, while in the remaining areas the increase is between 34 and 38 days (Fig. 8c). In addition, Ensemble model mean shows a lower increase of about 33-35 days in western, southern and mountain regions and 30 days in southeastern and inland regions (Fig. 8d).

Finally, the very important parameter of the maximum length of Humidex above 38°C (consecutive days with high discomfort) is illustrated in Figure 9. Both PRECIS (Fig. 9a) and Ensemble model mean (Fig. 9b) present the maximum length of about 60 days in inland and southeastern parts of Cyprus while southern, western and mountain regions present a maximum length of about 15 days in case of PRECIS (Fig. 9a) and 25 days in case of Ensemble model mean (Fig. 9b). As for near future changes, a noteworthy increase of about 40 days, is projected by PRECIS in the inland and southern-southeastern regions. Also, western parts show a lower increase of about 35 days while Troodos Mountain shows the lowest increase of around 28 days (Fig. 9c). On the other hand, Ensemble model mean projections show an increase of about 32-35 days in southern (Limassol) and southeastern parts (Larnaca). In inland and western regions the increase is around 30 days while in mountain regions is about 28 days (Fig 9d).

The overall findings of the analysis regarding both present-day climate and potential near future changes due to climate change with negative or positive impacts on human life are summarized in Table 2.

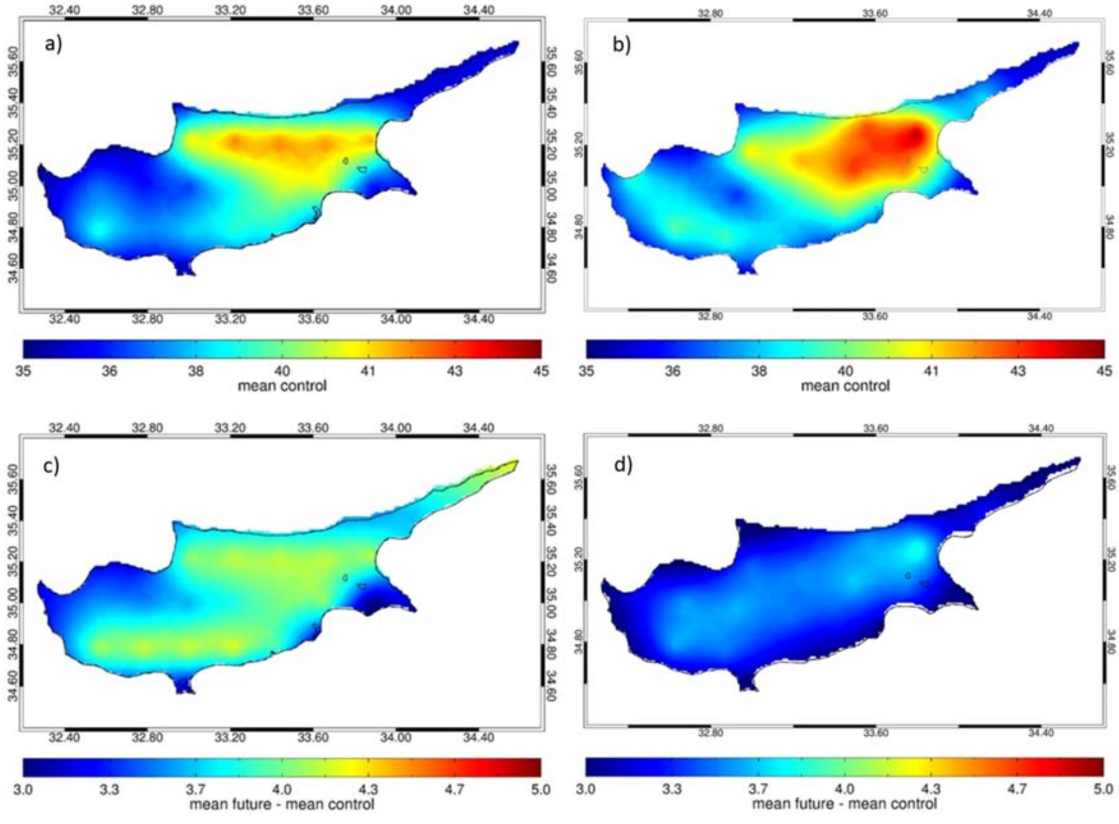

Figure 3: Average Summer Humidex for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Average Summer Humidex in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d).

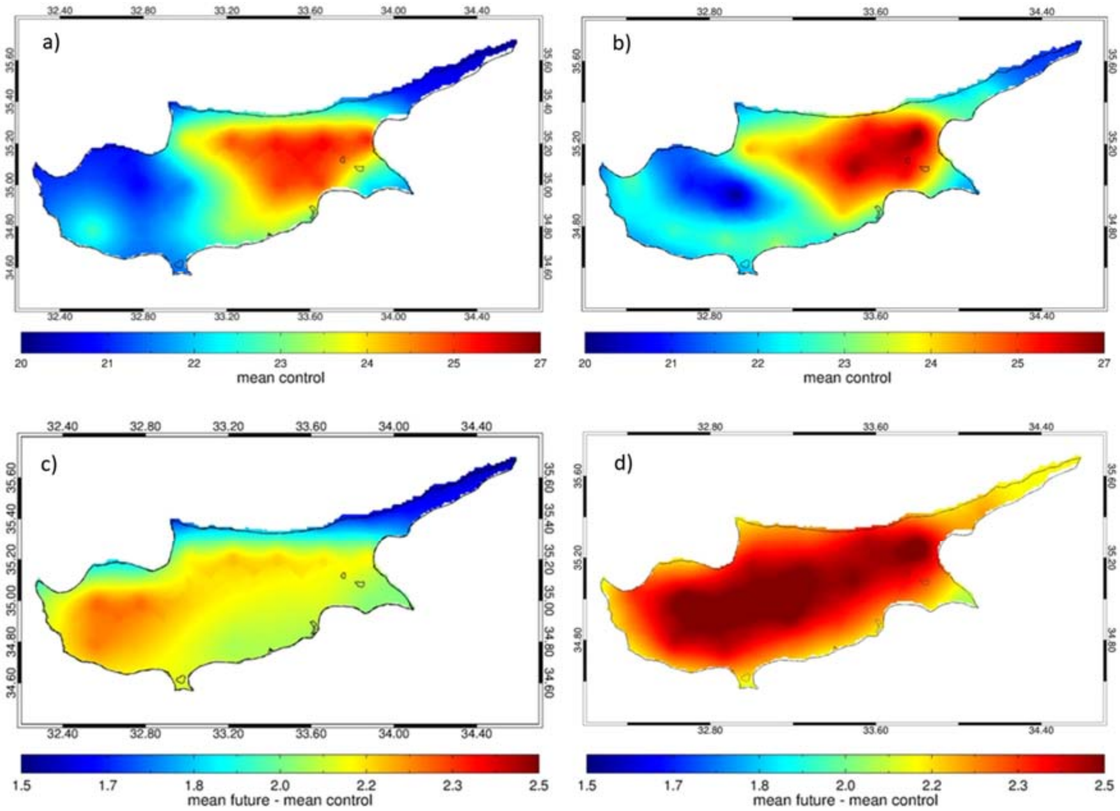

Figure 4: Average Spring Humidex for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Average Spring Humidex in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d).

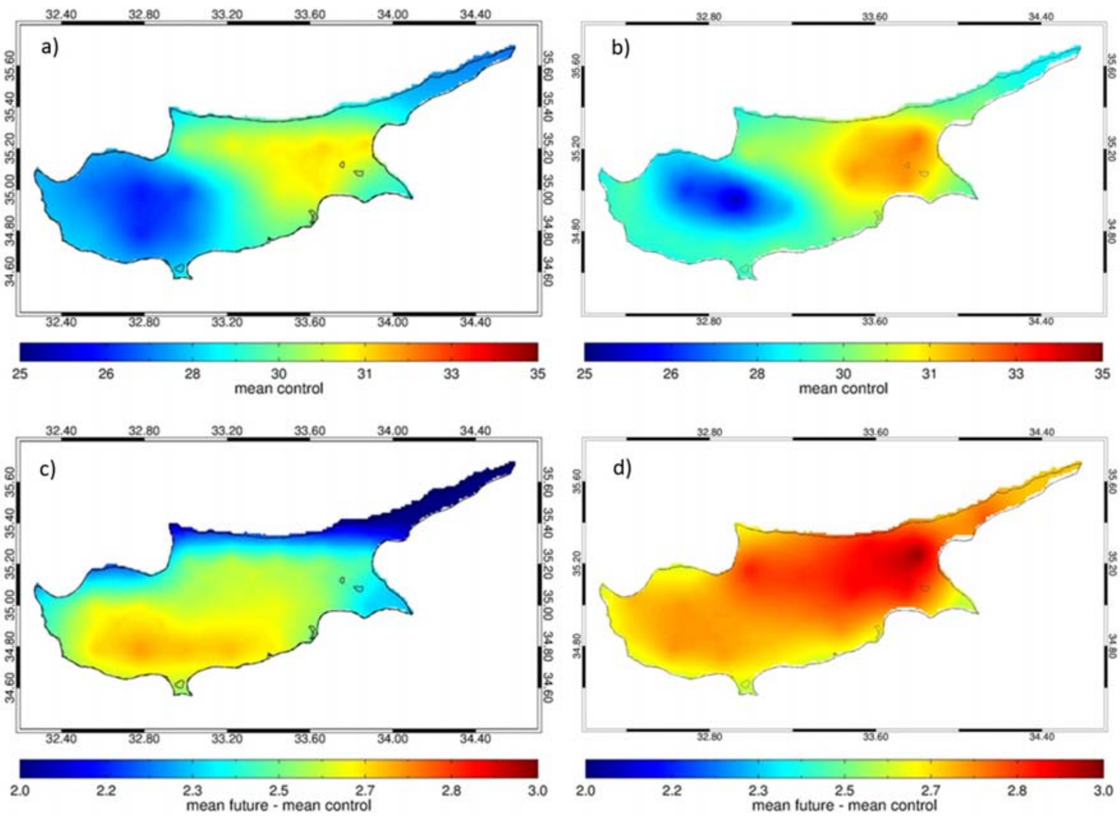

Figure 5: Average Autumn Humidex for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Average Autumn Humidex in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d).

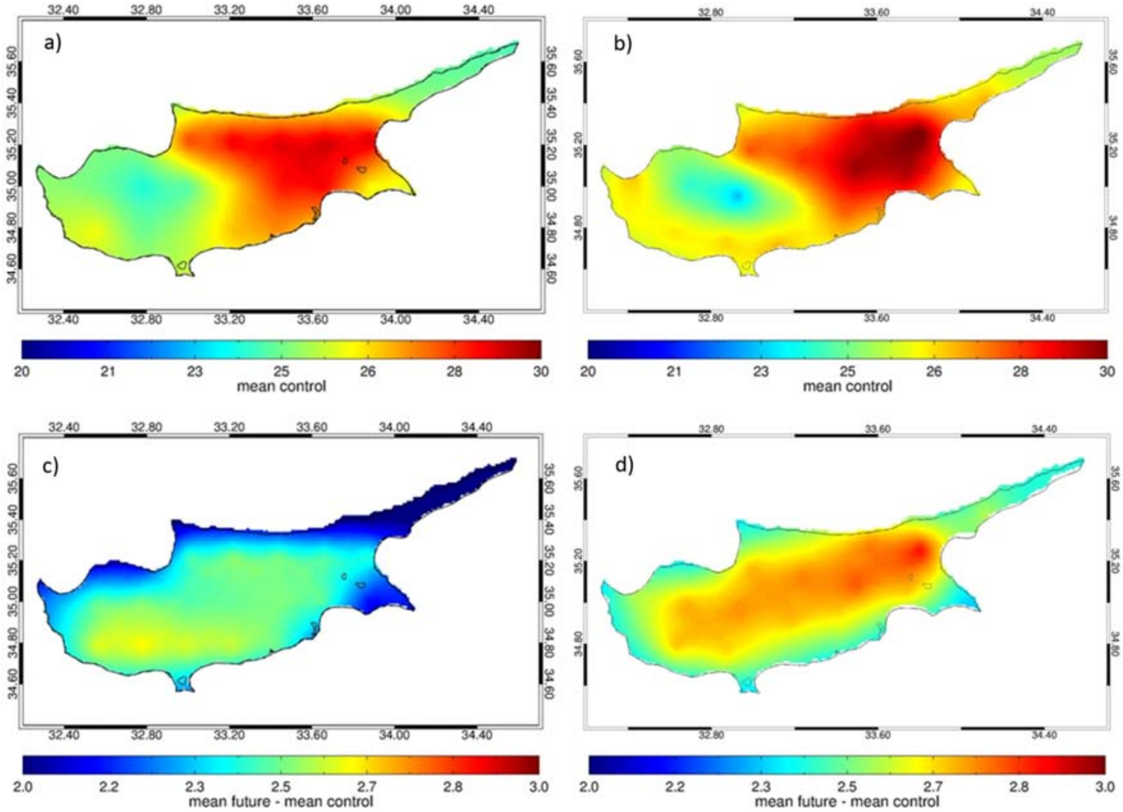

Figure 6: Average Annual Humidex for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Average Annual Humidex in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d).

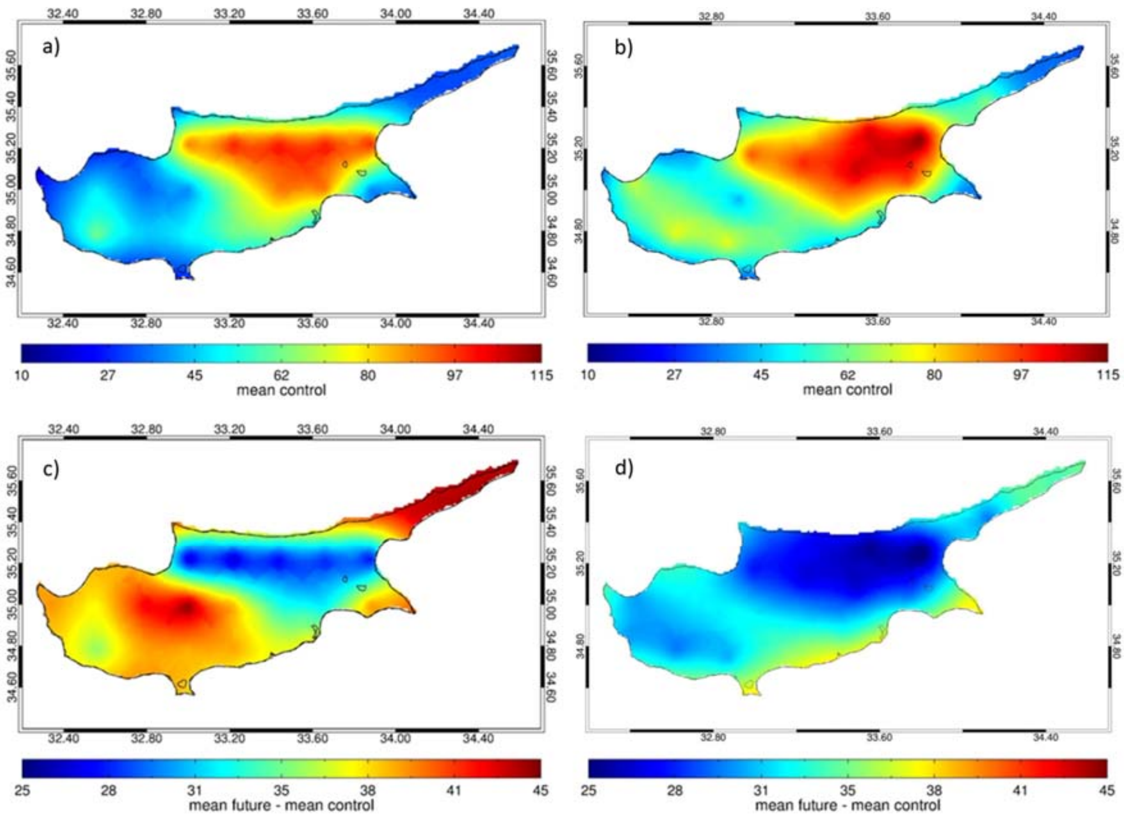

Figure 7: Number of days with Humidex > 38°C for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Number of days with Humidex > 38°C in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d).

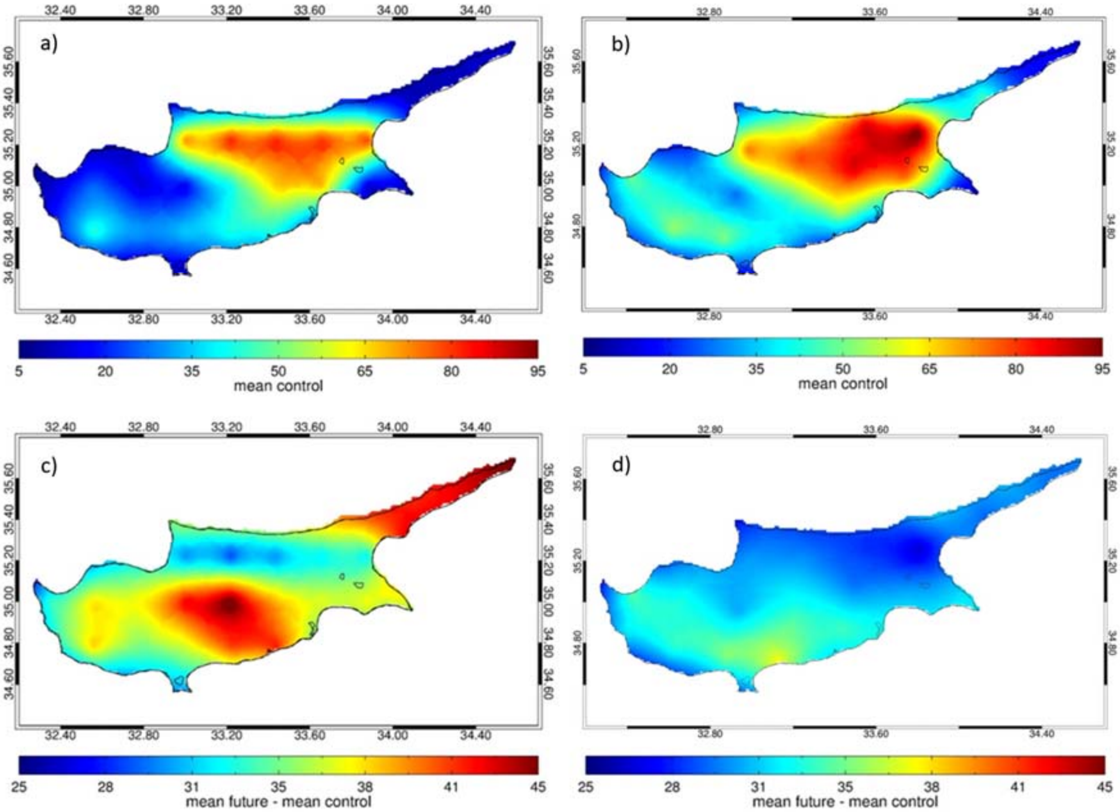

Figure 8: Number of days with Humidex > 40°C for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Number of days with Humidex > 40°C in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d).

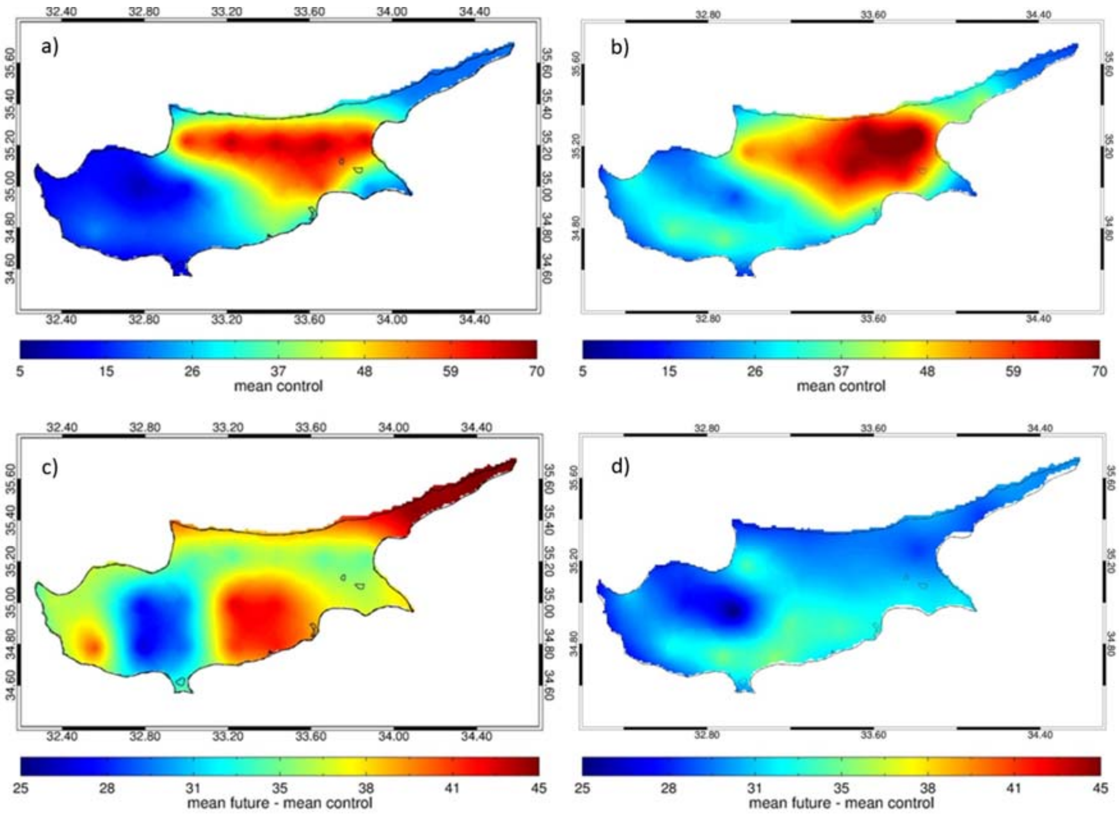

Figure 9: Maximum length of Humidex > 38°C for control period using PRECIS RCM model (a) and ENSEMBLE RCM models (b). Maximum length of Humidex > 38°C in the near future (Future – Control period) using PRECIS RCM model (c) and ENSEMBLE RCM models (d).

Conclusions

Taking into consideration the aforementioned indicators, the heat-related impacts of climate change could be a serious threat of public health in Cyprus in the near future. Considering the fact that the population groups that are most vulnerable to heat waves, namely the elderly, persons with pre-existing chronic diseases, people confined to bed, children, population groups with low socio-economic status, workers in outdoor environments, represent about 30% of Cyprus population and also that heat waves have a much bigger health impact in cities than in surrounding suburban and rural areas, the sensitivity and exposure of public health in Cyprus to heat waves as well as to the projected warming in general is considered high.

The public health response of Cyprus in heat waves is based at forecasting heat waves, issuing warnings and providing advices for self protection from heat waves, through the mass media (television, radio, newspapers, public websites etc.). In addition, during severe heat waves in Cyprus (as in summer of 2003), the government in order to protect its citizens from adverse health effects, recommends a curfew between the high risk hours of the day. Furthermore, working regulations prohibit outdoor labour work when temperature exceeds 40^{o}C. However, people frequently ignore curfews out of negligence, with all the adverse effects that may follow.

The majority of houses and indoor public areas as well as private trade facilities in Cyprus, are fully air-conditioned. Also, there are communal centers fully air-conditioned to accommodate people with no access to an air-conditioned environment during days of elevated temperatures. However, the protection of the population from heat waves is not always possible. Although the ability of the health care system of Cyprus to respond to heat related incidents is sufficient, it is the rapid nature of some heat-related health effects such as heat strokes that people do not make it to the hospital. Considering the abovementioned indicators, the adaptive capacity of Cyprus' public health to heat waves can be characterized as limited to moderate.

Finally, it can be inferred that the vulnerability that was identified through the present study, is related to the deaths and health problems related to heat waves and high temperatures considering that heat waves are quite frequent during summer in Cyprus and that a significant percentage of the population in Cyprus is particularly sensitive to heatwaves (elderly people), while the adaptive capacity is not satisfactory enough given that the protection of the population from heat waves is not always possible.

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Table 2: Aggregated results concerning HUMIDEX for the present-day climate (1961-1990) as well as near future (2021-2050) changes

	Western Regions		Mountain Regions		Inland Regions		Southern Regions		Southeastern Regions	
	PRECIS	ENSEMBLE	PRECIS	ENSEMBLE	PRECIS	ENSEMBLE	PRECIS	ENSEMBLE	PRECIS	ENSEMBLE
Control										
A. Summer HUM.	36	37	37	38	41	42	37	38	40	41
A. Spring HUM.	21	22	21	22	25	25	22	23	24	24
A. Fall HUM.	27	30	27	28	31	32	28	30	31	32
A. Annual HUM.	25	26	24	24	28	28	25	26	28	28
Nb of days with HUM. > 38 deg	45	60	45	60	90	90	45	60	90	90
Nb of days with HUM. > 40 deg	25	40	25	45	70	70	20	40	70	70
Max length of HUM. > 38 deg	15	25	15	25	60	60	15	25	60	60
Future Change (Future - Control)										
A. Summer HUM.	(+) 3.5	(+) 3	(+) 3.5-4	(+) 3.5	(+) 4	(+) 3.5	(+) 4	(+) 3.5	(+) 4	(+) 3.5
A. Spring HUM.	(+) 2	(+) 2	(+) 2	(+) 2.5	(+) 2	(+) 2.5	(+) 2	(+) 2	(+) 2	(+) 2
A. Fall HUM.	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5
A. Annual HUM.	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5	(+) 2.5
Nb of days with HUM. > 38 deg	(+) 40	(+) 29	(+) 41	(+) 32	(+) 33	(+) 28	(+) 40	(+) 32	(+) 33	(+) 28
Nb of days with HUM. > 40 deg	(+) 36	(+) 34	(+) 38-40	(+) 34	(+) 38	(+) 30	(+) 34	(+) 34	(+) 38	(+) 30
Max length of HUM. > 38 deg	(+) 35	(+) 30	(+) 28	(+) 28	(+) 40	(+) 30	(+) 35	(+) 33	(+) 40	(+) 34