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Heat exposure and the climate change beliefs in a Desert City: The case of Phoenix metropolitan area

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ABSTRACT

Beliefs in climate change are influenced by personal experiences and sociodemographic characteristics; yet justice considerations are often overlooked. We unveil the influence of these factors' on climate change beliefs in a large American city facing substantial climate change impacts, Phoenix, Arizona. Using the Phoenix Area Social Survey that includes data collected from (n = 806) households across fourteen cities in the Phoenix metropolitan area, we investigate what factors influence a belief that *"global warming and climate change are already occurring."* Engaging adaptive capacity and justice literatures with climate belief models, we find that belief in climate change and global warming is positively associated with race specifically other than non-Hispanic Whites, high levels of education, personal experience with heat-related illnesses, and liberal beliefs. Widespread agreement about climate change is found within the scientific community, but general populations, especially in the USA, lag behind in accepting climate change. Critically, there are important justice dimensions absent in the existing literature relevant to understanding belief in and the impacts of climate change. Unpacking these factors could help inform policy makers and civil society organizations in their efforts to design more "*just adaptation*" strategies.

1. Introduction

More than 70% of the world's population will live in cities by 2050 (UN, 2014), and climate change related events, such as heat and droughts, have huge impacts on the socio-ecological and technical systems in cities including increased risks of mortality (Klinenberg, 1999; Gasparrini et al., 2017). The IPCC Report (Stocker et al., 2012) shows that the effect of climate change coupled with urbanization increases heat exposure per capita. Critically, the impacts of heatwaves are not equally distributed among people living in urban areas, with some populations and communities more exposed and more vulnerable to climate change impacts or with less capacity to adapt (Balbus and Malina, 2009; Costello et al., 2009; Friel et al., 2011; Zografos et al., 2016). Climate change related weather events disproportionately affect the urban poor and aggravate socio-economic inequalities and environmental injustices in the cities of the US (Harlan et al., 2006; McCarthy et al., 2010; Hartz et al., 2013; Harlan et al., 2014).

Cities in the US have experienced severe weather events triggered by climate change for decades (Curriero et al., 2002; Madrigano et al., 2018; Hayden et al., 2011). Leiserowitz (2005) finds that most Americans continue to see climate change as a moderate risk and a future threat that will impact people and places that are geographically and temporally distant. Because of a lack of political will and intransigence of existing institutions and systems, the capacity for local adaptation has been questioned (Adger, 2006; O'Brien et al.,

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2007; Cutter and Finch, 2008; Krellenberg et al., 2017; Kuokkanen and Yazar, 2018; Yazar et al., 2020b). Some climate measures and actions perpetuate structures and systems that increase vulnerability, cause maladaptation, and increase climate injustices (Barnett and O'Neill, 2010; Kates et al., 2012; Hughes, 2013; Shi et al., 2016; Yazar et al., 2020a). There are feedbacks between local communities' capacity to adapt, proposed climate actions, and individual awareness and perceptions of climate change (Moser and Ekstrom, 2010).

Climate belief modelling often reveals a "white-male effect" (Albright and Crow, 2019; McCright and Dunlap, 2011; Kahan et al., 2007; Satterfield et al., 2004), providing some evidence of the racialized and gendered aspects of climate change beliefs. Yet, the modelling literature often does not engage with justice considerations. Building on a rich literature of environmental behaviour, we explore the role of race, ethnicity, gender, parenthood, and education (Kollmuss and Agyeman, 2002; Cottrell, 2003; Scannell and Gifford, 2010), while integrating perspectives of environmental justice and political ecology, such as socio-environmental conditions' uneven distribution across temporal and spatial scales (Cutter, 1995; Escobar, 1998; Heynen et al., 2006; Cole and Foster, 2001). The majority of climate change analyses and beliefs models are based on flood-related events (Spence et al., 2011; Walker and Burningham, 2011; Ogunbode et al., 2017; Albright and Crow, 2019) and we argue that our study makes an important contribution by using personal exposure data to analyse the effects of extreme heat on individuals' perceptions of climate change and global warming. To analyse the factors influencing climate change beliefs, we use the 2011 Phoenix Area Social Survey (n = 806) part of the Central Arizona Phoenix Long-Term Ecological Research (CAP LTER) (Harlan et al., 2017). We propose an integrated model of climate beliefs and justice which is essential to understanding climate adaptation in the context of one of the most climate change impacted cities in the USA, Phoenix, Arizona.

2. Theoretical context and hypotheses

Cities that are unable or unwilling to advance climate adaptation exacerbate power asymmetries and perpetuate climate injustice for vulnerable populations (Leiserowitz, 2005; Weber and Stern, 2011; Zografos et al., 2016). Adaptive capacity has its roots in vulnerability frameworks that include the key elements of exposure to hazards, sensitivity of populations or systems to absorb impacts, and adaptive capacity to cope with climate hazard (Turner et al., 2003; Adger, 2006; O'Brien et al., 2007; Cutter and Finch, 2008). Climate justice research focuses on reducing unjust adaptation policy (Paavola and Adger, 2006; Brulle and Pellow, 2006), such as by incorporating procedural, distributional and recognitional justice in the determination of households and communities' adaptive capacity (Schlosberg et al., 2017). Procedural justice deals with who is involved in the decision-making process and the fairness of institutions; whereas distributive justice focuses on who gets benefits and burdens of goods or services – more specifically how ecosystem services are equally distributed among citizens (Walker and Burningham, 2011; Thaler et al., 2018); and recognitional justice addresses the extent to which a government in power recognizes historical inequality and acknowledges communities' claims for equity (Young, 2011). Any violation of the aforementioned equity would trigger injustice that limits individuals' and groups' capacity to adapt to changing climate (Hayward, 2006; Roberts and Parks, 2009).

Heat is a dominant weather-related impact affecting human mortality and morbidity in the United States (Berko et al., 2014; Guo et al., 2018). Urban dwellers in cities most prone to drastic weather changes, such as Southwest, are increasingly vulnerable to the extreme summer temperatures with climate change (Chow et al., 2012; Hondula et al., 2018). Studies find that observing change in local weather is the strongest predictor of risk perceptions in many cities (Li et al., 2011; Zaval et al., 2014); on the other hand the literature is not consistent whether personal exposure to climate-related weather impacts or being socio-economically and environmentally vulnerable to local weather changes might strengthen belief in climate change (Akerlof et al., 2013; Brody et al., 2008).

Through a climate justice lens that connects adaptive capacity, exposure, and political ideology, we explore factors that affect climate beliefs in three models. Model 1 includes individuals' gender; age; race; education; employment status; and whether they had children under the age of six – which are highlighted under *Adaptive Capacity Model*. In Model 2 *Exposure Model*, we introduce people's experiences with the heat-related illnesses; and Model 3 *Ideology Model* their political beliefs.

2.1. Adaptive capacity model

The adaptive capacity model includes gender; age; race; education; employment status; and parenthood. Here, we generate Hypothesis (H) for each of the aforementioned variable.

2.1.1. Gender

Gender is frequently an important factor in adaptive capacity as well as climate change concern, and women are found more likely to believe in climate change (Akerlof et al., 2015; McCright and Dunlap, 2011; Malka et al., 2009; Brody et al., 2008; Hamilton and Keim, 2009).

H1. Women are expected to hold stronger beliefs that climate change and global warming are occurring than male individuals.

2.1.2. Age

Age is another important factor in perceiving climate change (McCright and Dunlap, 2011; Kahan et al., 2007; Marshall, 2004), and it is found that older adults (55 or older) are less likely to believe in the assessment of global warming in the US, compare to younger people (under 30) (Bohr, 2017).

H2. Individuals younger than 30 years of age are expected to hold stronger beliefs that climate change and global warming are

occurring than individuals 55 and older.

2.1.3. Race

Researchers show a racial and ethnic gap in concerns about climate change; people of color in the United States are more likely to express higher levels of concern about global warming than are their non-Hispanic White (referred to as Anglo in the southwestern USA) counterparts (McCright and Dunlap, 2011; McCright, 2010; Malka et al., 2009; Kahan et al., 2007; Satterfield et al., 2004). Compared to Anglo individuals, Blacks and Latinos express greater support for international and national climate policies (Pearson et al., 2017).

H3. Individuals other than non-Hispanic Whites are expected to hold stronger beliefs that climate change and global warming are occurring than individuals who identify themselves as White-Anglo.

2.1.4. Education

Hamilton (2011) argues that the level of education could be both positively or negatively associated with climate change concerns depending on political ideology, with communication and information technologies (e.g. Internet, cable news) allowing educated people to select information that aligns to their ideological views. Egan and Mullin (2012) find that individuals who experienced heat changes in their local environment and have lower education levels and weaker political party affiliations were more likely to believe in climate change.

H4. Individuals with the highest levels of education (completed college) are expected to hold stronger beliefs that climate change and global warming are occurring than individuals who are less educated.

2.1.5. Employment

People with full-time employment are found to have more concerns about the environment (Blocker and Eckberg, 1989; Albright and Crow, 2019), whereas McCright (2010) showed that employment status has no direct effect on climate change concerns.

H5. Individuals with full-time employment are expected to hold stronger beliefs that climate change and global warming are occurring than individuals with other than full-time work.

2.1.6. Parenthood

People with children are found more likely to believe in climate change (Flynn et al., 1994; Krannich and Albrecht, 1995; Poortinga and Pidgeon, 2003; Marshall, 2004). Their greater concern about climate change is associated with concern about how a changing climate will threaten their way of life (Davidson and Haan, 2012).

H6. Individuals with children under 6 years old are expected to hold stronger beliefs that climate change and global warming are occurring than individuals who have children older than 6 years or are not parents.

2.2. Exposure model

Heat exposure is recognized as one of the severe impacts to human health and wellbeing (Sheridan and Allen, 2018; Petitti et al., 2016; Harlan et al., 2013). Dramatic events such as the 1995 Chicago heat waves show that extreme weather events in urban areas disproportionately harm socio-economically disadvantaged groups with greater heat-related mortality and morbidity (Semenza et al., 1996; Klinenberg, 1999). Direct exposure to climate change-related events influences beliefs more than information about climate change in distant locations (Rudman et al., 2013; Whitmarsh, 2009). The relationship between exposure to climate related extreme weather events and climate change beliefs erodes overtime (Howe and Leiserowitz, 2013; Egan and Mullin, 2012). The magnitude of the event also matters; individuals experiencing climate change-related weather events with less damage are less likely to believe that climate change is occurring and also discount the seriousness of climate change (Saad, 2015). Building on this research, here we focus on the relationship between the severity of the extreme heat experience and the respondents' personal experience (the respondent versus an individual in the household) and respondents' beliefs in climate change.

H7. Individuals will report higher levels of agreement with the statement that global warming and climate change are occurring if; a) they have experienced heat-related illness, b) they called 911 or visited the hospital for heat-related illness, c) they have someone else in their household who had symptoms related to heat or high temperatures.

2.3. Ideology model

A relationship between climate change beliefs and political ideology in the US is well established (Zanocco et al., 2018; Bohr, 2017; Ogunbode et al., 2017; Palm et al., 2017; Hamilton et al., 2015a; Marquart-Pyatt et al., 2014; McCright and Dunlap, 2011; Dunlap and McCright, 2008). Researchers find that informing the public through scientific articles or reports does not alter their opinion about climate change (Hamilton et al., 2015b; Brulle et al., 2012; Kahan, 2015) as they selectively identify or dismiss scientific information through their social and political identities (Weber and Stern, 2011).

H8. Individuals who describe themselves as very liberal are expected to hold stronger beliefs that climate change and global warming are occurring than individuals who identify themselves as very conservative to somewhat liberal.

3. The data and methods

3.1. Study area

Urban development is transforming the Phoenician landscape, yet these transformations are largely perpetuating inequities (York and Boone, 2018). The city has a long history of environmental injustices, where race-based segregated urban planning embodied through redlining and industrial zoning of neighbourhoods settled by minoritized groups, has led to increased exposure to toxic environments for people of color for decades (York et al., 2014). Even though there are more progressive local governments, such as the city of Phoenix and the city of Tempe, that recognize climate change as a threat to the city's future and have adopted climate change agendas to tackle the heat issue specifically, it is well-documented by the science community (Jenerette et al., 2011; Chow et al., 2012; Harlan et al., 2013; York et al., 2014; Hondula et al., 2018) that socio-economic segregation and lack of political power in the Phoenix metropolitan area amplifies injustice as vulnerable peoples' voices are less likely to be heard by local governments (Bolin et al., 2005; Bolin et al., 2013; York and Boone, 2018).

Analyses show that the Phoenix Metropolitan Area could witness 42.2 extreme heat days per summer in the periods of 2041 to 2070 compared to 10.6 days for the periods of 1971 to 2000 (Grossman-Clarke et al., 2014). For a growing city of more than 4,8 million people (ACS, 2018) there are grave concerns about the future wellbeing of the most vulnerable residents. According to the Maricopa County Department of Public Health (MCDPH), 2019, in 2016, 130 people aged 50 years or older lost their lives due to heat exposure. Increasing impacts of the changing climate exacerbate historic environmental injustices increasing people's vulnerability in the Phoenix Metropolitan Area (Bolin et al., 2013). We aim to explore how perception of these changes is influenced by adaptive capacity, exposure, and ideology.

3.2. Data

To explore our hypotheses, we use the 2011 Phoenix Area Social Survey (PASS-2011) dataset, published by the Institute for Social Science Research at the Arizona State University (Harlan et al., 2017). The PASS-2011 dataset contains records from a total of 806 respondentsdrawn from the population of residents in 40 neighbourhoods in the Phoenix area using a random-probability sampling design. Five neighbourhoods from each group (for a total of 40 neighbourhoods) were selected with the objectives of creating a balanced sample of neighbourhoods that represent variation in ethnic/racial composition, homeowners and renters, and municipalities across the Phoenix Metro Area. The codebook of the PASS is also available through the CAP LTER data portal, giving detailed description of the survey design (Harlan et al., 2017). A total of fourteen different cities within the Phoenix area were reported as places of residence across PASS-2011 respondents. The survey was administered online, via telephone interviews, and via face-to-face interviews, achieving a 43.36% response rate at minimum in each neighbourhood.

3.2.1. Dependent variable

PASS-2011 respondents were provided with the introductory statement: *"Global warming and climate change refer to the idea that the earth's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the earth's climate may change as a result"*. They were then asked to express their extent of agreement or disagreement to the statement "*the effects of global warming and climate change are already occurring*" using a four-point scale containing the ordinal categories strongly agree; somewhat agree; somewhat disagree; and strongly disagree.

Responses to the above question were re-coded into a dichotomous variable, distinguishing between respondents who strongly agreed to the statement (coded as 1) and respondents who somewhat agreed, somewhat disagreed or strongly disagreed to the statement (coded as 0). Specified in this binary form, the dependent variable focuses on respondent attitudes at the extreme end of agreement to the statement versus attitudes ranging from moderate agreement to strong disagreement to the statement.

3.2.2. Mode-effect control variable

The study uses a PASS-2011 variable that records the mode in which each respondent completed the survey (i.e. online, telephone, or face-to-face mode). The variable is used to account for the possibility of differential response patterns being observed for PASS-2011 respondents who completed the survey in different modes. PASS-2011 respondents who completed the survey in face-to-face mode were treated as the reference category against which respondents in other modes were compared with regard to the dependent variable of the study.

3.2.3. Socio-demographic control variables

The study uses a range of PASS-2011 variables that record self-reported socio-demographic information about respondents at the time of the survey:

Respondent *gender* distinguishes between respondents who identify as male versus female at the time of the survey. PASS-2011 respondents who identified as female were treated as the reference category against which respondents who identified as male were compared with regard to the dependent variable of the study.

Respondent *age* at the time of the survey was originally recorded in the PASS-2011 dataset as continuous integers ranging from 18 to 92 years of age. These were banded into three categories or roughly similar frequencies; i.e. 18 to 40 years of age, 41 to 56 years of age, and 57 years of age or older. PASS-2011 respondents in the youngest age group (i.e. 18 to 40 years of age) were treated as the reference category against which respondents in other age groups were compared with regard to the dependent variable of the study.

Respondent *racial and ethnic background* in the PASS-2011 dataset was originally recorded across seven categories (i.e. White; Black; Asian; American Indian; Hispanic; Multiracial; or any other racial background). For our study, the original categories were further grouped into two overarching categories distinguishing between respondents who had identified as non-Hispanic White versus respondents who had identified as other than non-Hispanic White (with the latter category containing respondents who had identified as Black, Asian, American Indian, Hispanic, Multiracial, or any other racial background not specifically stated). PASS-2011 respondents in the other than non-Hispanic White group were treated as the reference category against which respondents in the non-Hispanic White group were compared with regard to the dependent variable of the study.

Respondent *highest level of education* completed at the time of the survey was originally recorded in the PASS-2011 dataset across seven categories (i.e. grades 1 to 8; grades 9 to 11; high school; community college; vocational or technical school; college; and graduate or professional school). For our study, the original categories were grouped into two broader categories distinguishing between respondents who had reported having completed any of grades 1 to 8, grades 9 to 11, high school, community college, and vocational or technical school versus respondents who had reported having completed college or graduate and professional schools. The former category was treated as the reference category against which respondents in the latter category were compared with regard to the dependent variable of the study.

The PASS-2011 dataset recorded respondent *employment status* at the time of the survey across seven categories (i.e. working full time; working part time; full-time student; homemaker; retired; unemployed; and any other employment status not specifically stated). Our study grouped these original categories into two overarching categories distinguishing between respondents who at the time of the survey reported being in full-time work versus respondents who at the time of the survey reported any employment status other than full-time work. The latter category was treated as the reference category against which respondents in former were compared with regard to the dependent variable of the study.

Finally, the PASS-2011 dataset recorded whether respondents had *children under the age of six* at the time of the survey. Respondents who had reported not having children under the age of 6 were treated as the reference category against which their counterparts were compared with regard to the dependent variable of the study.

Table 1
Distribution PASS-2011 variables considered by this study.

Variable	Distribution description	Count of respondents	Proportion of respondents against complete sample size (806 respondents)
Respondent's extent of agreement with the statement "*the effects of global warming and climate change are already occurring*"	Strongly agree	362	45%
	Somewhat agree, somewhat disagree, strongly disagree	408	51%
Survey completion mode	Online response mode	629	78%
	Telephone response mode	95	12%
	Face-to-face response mode	82	10%
Respondent gender	Female	453	56%
	Male	345	43%
Respondent age	18–40 years of age	269	33%
	41–56 years of age	265	33%
	57 years of age or older	252	31%
Respondent racial background	Non-Hispanic White	530	66%
	Other than non-Hispanic White (Black, Asian, American Indian, Hispanic, Multiracial, or any other non-White racial background not specifically stated)	260	32%
Respondent highest level of school completed	College, bachelor's degree, graduate, professional school	371	46%
	Grades 1–11, high school, community, vocational, technical	424	53%
Respondent employment status	In full-time work	371	46%
	Other than full-time work (part-time work, full-time student, homemaker, retired, unemployed, or any other employment status not specifically stated)	421	52%
Respondent has children under 6 years of age	Yes	115	14%
	No	691	86%
Respondent had symptoms related to heat or high temperatures	Yes	203	25%
	No	535	66%
Someone else in respondent's household had symptoms related to heat or high temperatures	Yes	158	20%
	No	566	70%
Respondent called 911 or visited the hospital for heat-related illness	Yes	32	4%
	No	765	95%
Respondent political ideology	Very liberal	60	7%
	Other than very liberal (somewhat liberal, moderate, somewhat conservative, or very conservative)	648	80%

3.2.4. Heat exposure

To allow us to explore the relationship between the dependent variable and PASS-2011 respondents' experiences of heat-related symptoms or illness, our study employs three PASS-2011 variables which use yes-or-no answers to record whether PASS-2011 respondents "*had experienced symptoms related to heat or high temperatures*"; "*lived in households where others had experienced symptoms related to heat or high temperatures*"; or "*had dialled 911 or had visited a hospital due to heat-related illness*" during the summer of 2010. For each of the three variables, respondents who had answered "no" were treated as the reference category against which their counterparts were compared with regard to the dependent variable of the study.

3.2.5. Political beliefs

Respondent political ideology, as self-reported at the time of the survey, was recorded in the PASS-2011 dataset across five categories (i.e. very conservative; somewhat conservative; moderate; somewhat liberal; and very liberal). The original categories were grouped into two overarching categories distinguishing between respondents who had self-reported being very liberal as opposed to respondents who had self-reported being somewhat liberal, moderate, somewhat conservative, or very conservative. The latter category was treated as the reference category against which respondents in the former category were compared with regard to the dependent variable of the study. By grouping respondents in this fashion, the variable focuses on respondent attitudes at the extreme end of self-reported liberal political affiliation versus other political attitudes.

Table 1 presents the distribution properties of the variables used in the study.

3.3. Approach to the analysis

A series of models were fitted using selected variables from the PASS-2011 dataset. Broadly speaking, the models investigated the relationship between a binary dependent variable (which distinguishes between respondents who strongly agree with the statement that the effects of global warming and climate change are already occurring versus respondents who do not) and a series of independent and control variables. To quantify the strength of association between independent and control variables, and explore multicollinearity concerns, the Cramer's V metric was used (Wang, 1986). Cramer's V values do not highlight strong associations between the independent and control variables (see Annex I).

Table 2
Fixed effects in two-level logistic regression models with random intercept at city level predicting strong agreement with the statement "the effects of global warming and climate change are already occurring" [vs. moderate agreement, moderate disagreement, or strong disagreement].

Variable	Category [vs. reference category, if predictor is categorical]	Coefficient (standard error)		
		Model 1	**Model 2**	**Model 3**
Intercept	–	1.651*** (0.388)	1.450*** (0.419)	1.4711*** (0.431)
Survey completion mode	Online **[vs. face-to-face]**	−1.010*** (0.304)	−1.041*** (0.330)	−1.172*** (0.363)
	Telephone **[vs. face-to-face]**	−0.427 (0.357)	−0.562 (0.383)	−0.717* (0.415)
Respondent gender	Male **[vs. female]**	−0.178 (0.161)	−0.186 (0.172)	−0.083 (0.186)
Respondent age	41 to 56 years of age **[vs. 18 to 40]**	0.054 (0.206)	0.062 (0.221)	0.083 (0.244)
	57 years of age or older **[vs. 18 to 40]**	−0.127 (0.225)	−0.008 (0.245)	−0.018 (0.264)
Respondent racial background	Non-Hispanic White **[vs. other than non-Hispanic White]**	−0.879*** (0.189)	−0.830*** (0.203)	−0.874*** (0.220)
Respondent highest level of school completed	College, graduate / professional school **[vs. grades 1 to 11, high school, community college, vocational / technical school]**	0.397** (0.170)	0.342* (0.182)	0.345* (0.194)
Respondent employment status	In full-time employment **[vs. any other employment status]**	−0.109 (0.175)	−0.122 (0.188)	−0.271 (0.204)
Respondent has children under 6 years of age	Yes **[vs. no]**	−0.277 (0.249)	−0.145 (0.275)	−0.035 (0.301)
Respondent had symptoms related to heat or high temperatures	Yes **[vs. no]**		0.526** (0.240)	0.510** (0.256)
Someone else in respondent's household had symptoms related to heat or high temperatures	Yes **[vs. no]**		0.162 (0.258)	0.275 (0.274)
Respondent called 911 or visited the hospital for heat-related illness	Yes **[vs. no]**		0.992** (0.497)	1.069* (0.547)
Respondent political ideology	Very liberal **[vs. moderately liberal, moderately conservative, very conservative]**			1.729*** (0.372)
Model metrics				
Sample size		730	646	583
Akaike Information Criterion		966.9	848.3	809.9

Statistical significance identifiers: {≤0.001: '***'}; {0.05: '**'}; {0.10: '*'}.

Given the geographically nested structure of the PASS-2011 data, the study first explored whether two-level logistic regression models with a random intercept at city level may be a more appropriate modelling scheme compared to simpler, single-level models (without city-level random effects). Two-level logistic regression models with a random intercept at city level were deemed as the preferred modelling option, as the analysis failed to reject the hypothesis that between-city variability in relation to the dependent variable is zero (Likelihood-ratio statistic = 14.888; df = 1; p-value <0.001). In total, three models were fitted to explore dependencies between the dependent variable and the selected independent and control variables. Goodness-of-fit for the reported models was evaluated using the Akaike Information Criterion (AIC) metric. Reported models were also tested for singularity, to ensure that all elements of their corresponding variance-covariances matrices can be assumed to be non-zero. Only non-singular models are reported in this paper (singularity tolerance = 0.00001).

Given the modest sample size available to this study, the risk of singularity limits the number of variables that any single model can account for without demonstrating signs of overfitting, as indicated by testing positive for singularity. The authors of this study considered a large number of PASS-2011 (control and independent) variables, but ultimately adopted the theoretically driven set of control and independent variables presented here while managing and mitigating the risk that observations made by this study become highly specific or *overfitted* to the PASS-2011 responding sample. The analysis for this study was conducted within the R environment for visual and statistical analysis (R Core Team, 2013).

4. Results

Table 2 presents fixed affects in three two-level logistic regression models with a random intercept at the city level and fixed effects at respondent level; the models explore the relationship between respondents' degree of agreement with the statement "*the effects of global warming and climate change are already occurring*" (for simplicity, *the target statement*), mode-effect and socio-demographic controls, their self-reported experiences of heat-related symptoms or illness, and their political beliefs. (See Table 3.)

4.1. Mode-effect control variables

Models 1, 2, and 3 suggest that PASS-2011 respondents who completed the survey online have a statistically significant lower propensity to strongly agree with the target statement compared to their counterparts who completed the survey face-to-face. Some of the models fitted for this study suggest that PASS-2011 respondents who completed the survey over a telephone interview may have a lower propensity to strongly agree with the target statement compared to respondents who completed the survey face-to-face (Model 3). However, this observation appears to be unstable across the model variations explored in this study.

4.2. Adaptive capacity model

Statistically significant relationships were identified between climate change beliefs and *race and ethnicity* and *education.* We did not observe statistically significant effects for the remainder of respondent socio-demographic characteristics that our study considered (i.e. respondents' gender; age; employment status; or whether they had children under the age of six).

Models 1, 2 and 3 suggest that PASS-2011 respondents' *race and ethnicity* is linked to their propensity of strongly agreeing with the target statement in a statistically significant fashion. Specifically, respondents from non-Hispanic White backgrounds appear less likely to strongly agree with the target statement compared to their counterparts from other race and ethnic backgrounds. These patterns are observed when survey mode and other socio-demographic features are controlled for (Model 1); and when the survey mode, other socio-demographic features, respondents' self-reported experiences of heat related symptoms or illness are controlled for (Model 2); and when survey mode, other socio-demographic features, respondents' self-reported experiences of heat related symptoms or illness, and their political beliefs are controlled for (Model 3). These observations support our *H3* hypothesis.

Table 3
Overview of statistically significant fixed effects.

Variable	Category [vs. reference category, if predictor is categorical]	Coefficient (standard error)		
		Model 1	Model 2	Model 3
Survey completion mode	Online **[vs. face-to-face]**	−	−	−
	Telephone **[vs. face-to-face]**			−
Respondent racial background	Non-Hispanic White **[vs. other than non-Hispanic White]**	−	−	−
Respondent highest level of school completed	College, graduate / professional school **[vs. grades 1 to 11, high school, community college, vocational / technical school]**	+	+	+
Respondent had symptoms related to heat or high temperatures	Yes **[vs. no]**		+	+
Respondent called 911 or visited the hospital for heat-related illness	Yes **[vs. no]**		+	+
Respondent political ideology	Very liberal **[vs. moderately liberal, moderately conservative, very conservative]**			+

Effects annotation: {statistically significant positive effect: '+'}; {statistically significant negative effect: '-'}.

Respondents' *highest level of educatio*n is linked to their propensity of strongly agreeing with the target statement in a statistically significant fashion, as suggested by Models 1, 2 and 3. More specifically, respondents with college or professional qualifications appear more likely to strongly agree with the target statement compared to their counterparts with highest education qualifications at lower levels. These patterns are observed when the aforementioned variables are controlled for in Models 1, 2 and 3,supporting our *H4* hypothesis.

4.3. Exposure model

Models 2 highlights statistically significant positive relationships between PASS-2011 respondents' propensity to report that they strongly agree with the target statement and whether they self-report "*having experienced symptoms related to heat or high temperatures*" as well as whether they self-report "*having called 911 or having visited the hospital due to heat-related illness*" during the summer of 2010. These observations confirm our *H7* hypothesis with an exception. The analysis does not suggest a statistically significant relationship between respondents' propensity to strongly agree with the target statement and whether they self-report that "*someone else in their household has experienced symptoms related to heat or high temperatures*" [*H7c*]. Hence, our *H7* a and b hypotheses are confirmed.

4.4. Ideology model

Controlling for PASS-2011respondents' socio-demographics, self-reported experiences of heat related symptoms or illness as well as for survey mode, the study observes that respondents who describe themselves as very liberal have a greater propensity to strongly agree with the target statement than their counterparts who position themselves differently across a spectrum of political ideologies ranging from very conservative to somewhat liberal (Model 3). Hence, our *H8* hypothesis is confirmed.

5. Discussion

In this paper, we worked with individual-level data and environmental behaviour and climate perception models in order to examine how residents ($n = 806$) in the Phoenix Metro Area perceive climate change and global warming and how their beliefs are associated with their socio-demographic indicators, heat exposure, and political beliefs.

5.1. Adaptive capacity model

Interestingly, unlike the existing literature that finds positive relationships between climate change beliefs and *socio-demographic indicators* such as age (Bohr, 2017), gender (Akerlof et al., 2015; McCright and Dunlap, 2011; Malka et al., 2009; Brody et al., 2008; Hamilton and Keim, 2009), employment (Blocker and Eckberg, 1989; Albright and Crow, 2019), and parenthood (Flynn et al., 1994; Krannich and Albrecht, 1995; Poortinga and Pidgeon, 2003; Marshall, 2004); we did not find any positive association between belief in climate change and global warming, and the aforementioned socio-demographic variables.

Education, specifically, respondents with college or professional qualifications appear more likely to strongly agree that climate change and global warming is occurring, confirming similar findings (Hamilton and Keim, 2009; Marshall et al., 2006). Our results raise important questions in terms of knowledge generation and awareness for climate change through formal, and informal, education, and whether education is able to shift the terms of climate change debate from zero-sum understanding.

Importantly, *race and ethnicity* are significant (McCright and Dunlap, 2011; McCright, 2010; Malka et al., 2009; Kahan et al., 2007; Satterfield et al., 2004), and similarly we observe that non-Hispanic White individuals are less likely believe that climate change and global warming is occurring. Critically, this illuminates the need to consider justice in the context of climate change beliefs, especially as urban planning and infrastructure in the Phoenix Metro Area are inadequate to address the needs of the vulnerable. Higher-income and predominantly non-Hispanic White neighbourhoods are less exposed and more "comfortable places" (according to a thermal comfort index) than lower-income Hispanic neighbourhoods in the Phoenix Metro Area (Harlan et al., 2006). People of color have been historically exposed to a concentration of industrial hazards, redlining in urban planning, and their properties are expropriated due to the construction of infrastructures (Bolin et al., 2013). The current increase in heat coupled with changing climate consequently disproportionately affects the adaptive capacity of people of color who are systematically excluded through socio-spatial and political economic processes.

5.2. Exposure model

The findings from this study related to *heat exposure* suggest that personally experiencing symptoms related to heat or high temperatures is a stronger predictor of belief in climate change and global warming; this personal experience is more influential than living in a household where others may have had experienced similar symptoms. This supports findings that show beliefs in climate change and global warming are highly positively dependent on personal experience with heat-related illnesses (Zanocco et al., 2018; Konisky et al., 2016; Rudman et al., 2013; Whitmarsh, 2009).

5.3. Ideology model

Political ideology and worldviews dominate acceptance or rejection of climate science compared to any other factors (Kahan, 2015).

Showing the poll results from 1997, 2007 and 2016, Dunlap et al. (2016) report that climate change beliefs widened between people affiliated with the Democratic and Republican parties. Democrats consistently increased their agreement to the given statement "the effects of global warming have already begun" (52% in 1997; 70% in 2007; 75% in 2016), whereas Republicans grew increasingly sceptical (48% in 1996; 45% in 2007; 41% in 2016). Our analyses confirm the literature and show that people who identify themselves as very liberal (Zanocco et al., 2018; Bohr, 2017; Ogunbode et al., 2017; Palm et al., 2017; Hamilton et al., 2015a; Marquart-Pyatt et al., 2014;McCright and Dunlap, 2011; Dunlap and McCright, 2008) are more likely to believe that climate change is happening.

5.4. Integrated justice model

Engaging environmental behaviour and justice approaches with climate belief models, we find that climate change and global warming are associated with race, ethnicity, and high levels of education. We have also found that beliefs in climate change in urban populations are highly influenced by heat exposure and political ideology. These results suggest that there are important justice dimensions influencing beliefs, as well as impacts of climate change. Race and ethnicity, education, heat exposure, and political beliefs are the indication of institutionally constructed vulnerabilities that are embedded in individuals' climate change beliefs. Performing research to better characterize the institutional and organizational settings that exacerbate climate change vulnerabilities among urban population is critical to disseminate awareness about climate change and to take tangible actions to mitigate its impact. Politically, Arizona has been dominated by politicians who publicly reject human impact on climate change and resist to take actions, although the state is moving toward more liberal positions, as the demographics of the population change (younger, more college education, and more non-Hispanic White voters) (Fink, 2019), more research is needed to assess how climate adaptation policy (and other related policy) decisions at the local, state, and federal level exacerbate vulnerability for those who reside in less resilient neighbourhoods.

6. Conclusion

There are pervasive inequities in the distribution of climate change impacts in urban areas and climate justice must be contextualized from vulnerability and adaptation perspectives. Further climate belief models must engage with environmental justice studies in order to recognize issues of justice in urban climate adaptation. The empirical research from various urban areas find that exposure to climate change impacts are distributed unevenly. Further, local attempts to adapt to climate change are often limited by local governments' capacity; in contrast, major development projects occur through government collaboration with large businesses, which attract affluent residents, and may further displace the most vulnerable.

Analysing beliefs in climate change among urban populations is one way to unveil the characteristics of their vulnerabilities and lack of adaptive capacity that are embedded in their perceptions. Local climate belief analyses must engage with adaptive capacity and justice perspectives to better capture the drivers of climate change perceptions. That said, this study investigated predictors of global warming and climate change beliefs by looking at heat-related illness, socio-demographic, and attitudinal dynamics in the Phoenix Metropolitan Area. Based on the results, we found that personal experience with heat-related illnesses is a stronger predictor of belief in climate change and global warming than living in a household where others may have had experienced similar symptoms. Race and ethnicity, higher education level, and strong liberal beliefs are positively related to beliefs in climate change and global warming, while other sociodemographic variables including gender, age, employment status, and parenthood were not found to be significant.

Climate change beliefs are complex and mediated by many factors, but there is evidence in our study that personal experiences with heat-related illness may influence climate change beliefs. Empowering people, recognising social and political processes that cause maladaptation, and creating governance systems that are inclusive, redistribute benefits and making access to resources more equal is vital for increasing adaptive capacities. Considering the increasing temperatures and asymmetries in social, economic and political power, further studies must consider focusing on the existing institutional and organizational barriers that exacerbate unjust adaptation measures and implementations for the urban population in the Phoenix Metro Area. The results of this study could also be an important consideration in the design of effective climate change strategies among key urban agents from the different levels of governments and civil societies in the Phoenix Metropolitan Area.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.uclim.2020.100769.

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