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Effects of local drought condition on public opinions about water supply and future climate change

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Abstract A growing body of research indicates that opinions about long-term climate change and other natural resource issues can be significantly affected by current weather conditions (e.g., outside air temperature) and other highly contingent environmental cues. Although increased severity and frequency of droughts is regarded as a likely consequence of anthropogenic climate change, little previous research has attempted to relate the experience of drought with public attitudes about water supply or water-related climate change issues. For this study, a large set (n=3,163) of public survey data collected across nine states of the

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southern United States was spatio-temporally linked with records of short-term (~12 weeks) and long-term (~5 years) drought condition at the level of each respondent's zip code. Multivariate ordinal logistic regression models that included numerous other independent variables (environmental ideology, age, gender, education, community size, residency duration, and local annual precipitation) indicated highly significant interactions with long-term drought condition, but showed no significant effect from short-term drought condition. Conversely, attitudes about water-related climate change showed highly significant interactions with short-term drought, with weaker to no effects from long-term drought. While the finding of significant effects from short-term drought condition on opinions about future drought is broadly consistent with previous public opinion research on climate change, the finding of water supply attitudes being more responsive to longer term drought condition is, to our knowledge, a novel result. This study more generally demonstrates the methodological feasibility and applied importance of accounting for local drought condition when public opinion information is used to evaluate outreach programs for water conservation and climate change.

1 Introduction

One of the most serious expected consequences of climate change is increases in the frequency and severity of droughts across many regional and local areas. Communication of future water supply risks associated with climate change and promotion of increased water conservation as a climate adaptation strategy is therefore a standard components of many water outreach and planning programs (e.g., Bjorkland and Pringle 2001; Cohen et al. 2006; Rosenzweig et al. 2007). Because such outreach programs are specifically intended to educate the public in ways that change attitudes and, ultimately, behaviors, they often are assessed through broad-based survey instruments designed to gauge longitudinal effectiveness of program activities and outreach materials on public opinions (see e.g., Shepard 2002; Lorenzoni and Pidgeon 2006; Jackson-Smith and McEvoy 2011).

Qualitative observations generally support the intuitive notion that the onset of severe drought conditions tends to increase public interest and receptivity to water conservation programs (Jensen 1996; Delorme et al. 2003; Casagrande et al. 2007). Although not directly focused on drought experience, a more recent body of psychological literature more specifically indicates that contingent environment factors such as current outdoor temperature and condition of indoor vegetation (Gueguen 2012) can have significant impacts on public opinions about climate change (Joireman et al. 2010; Li et al 2011; Weber and Stern 2011; Akerlof et al. 2013). However, surprisingly little previous quantitative research has attempted to link spatio-temporally specific measures of drought condition and severity to public attitudes about water resources or climate change phenomena.

Previous studies that have examined effects of precipitation conditions on public opinions include the work of Diggs (1991), Trumbo et al. (1999), and, more recently, Safi et al. (2012). Working with Great Plains farmers, Diggs (1991) found that certainty about the existence of long-term climatic change was stronger among farmers in North Dakota, which had experienced severe drought conditions throughout much of the 1980s, as compared to farmers in an area of northeastern Colorado that had been generally wet over this same time period. Trumbo et al. (1999) conducted a post hoc analysis of water conservation attitudes collected from two surveys in Reno, NV, and found that public attitudes were significantly more favorable to water conservation programs during a drought period as compared to a comparatively wet period.

Work by Safi et al. (2012) with Nevada farmers found that higher livelihood dependence on agriculture and higher education both were associated with an increased concern for climate change, but that differences in relative local water stress was not a significant predictor of climate change concern. However, we note that the water stress metric used by Safi et al. (2012) did not explicitly include direct measures of local drought condition, but was instead was based on calculations of water availability, water demand, and population at a zip code level.

The findings by Trumbo et al. (1999) led them to warn that unmeasured variations in antecedent rainfall and/or local drought conditions could introduce unaccounted biases into opinion surveys about water resource and conservation issues. However, the recommendation of Trumbo et al. (1999) to include information about antecedent precipitation conditions when assessing public opinions about water resource or, by extension, climate change issues has been rarely implemented to date (as also noted, for example, by Safi et al. 2012). This continued disconnect, in our view, is largely a function of the perceived difficulty of incorporating spatio-temporally relevant precipitation or drought severity information into broad-based public opinion survey instruments.

For this study, we developed a geographic information system (GIS) method for linking drought condition data archives maintained by the U.S. Drought Monitor (NDMC, USDA, and NOAA 2012) to public survey information at a zip code level. We then used this method to link spatio-temporal drought information over a short-term (~12 weeks) and long-term period (~5 years) to respondent data gathered from a water survey instrument as distributed in the southern U.S. states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas during various periods between 2008 and 2010. Many areas within these states experienced severe drought conditions during and prior to their survey periods, including significant droughts experienced in Oklahoma and Texas during 2006 (Dong et al. 2011) and in Georgia, Tennessee, Florida, and Alabama during 2007 (Manuel 2008).

Our basic research hypothesis was that higher levels of recent drought at the zip code level would be associated with respondents expressing an increased level of concern about the both the condition of local water supplies and risks associated with future drought occurrence due to climate change. To test this hypothesis, a series of multivariate ordinal logistic regression (logit) models were used to analyze the dependence of respondent opinions to short-term and long-term drought condition. Other predictor variables including environmental ideology, age, gender, education, community size, residency duration, and local mean annual precipitation were also analyzed for the purpose of both comparison and control. While the study's results generally confirmed the general research hypothesis, they also suggest that attitudes about water resources and climate change may be affected differently by the long-term duration of persistent droughts and short-term immediacy of current drought conditions. More broadly, we believe that the study demonstrates both the feasibility and importance of including measures of local drought condition when analyzing public opinion data related to water resource and climate change issues.

2 Materials and methods

2.1 National water survey needs assessment program

The survey data for this study were obtained from the National Water Survey Needs Assessment Program (NWSNAP), a long-term (2001 to 2010) research initiative funded by the U.S. Department of Agriculture (USDA) for the purpose of collecting detailed public opinion data about water resources across the U.S. (Mahler et al. 2013). Survey instruments for the full NWSNAP were distributed to a random selection of residential addresses at different times across a total of 41 participating states using a multiple step mailing procedure generally known to produce high response rates (Dillman 2000; Edwards et al. 2014).

The content of survey instruments for the NWSNAP was developed at a state and regional level through consultations with regional leaders in water education and extension programming. Although some survey questions remained consistent across all 41 participating states, other questions were developed for individualized implementation in specific regions and/or states. Due to the consistency of survey instruments and questions among states within the same region, most previous research using the NWSNAP has been conducted at the state or regional level (e.g., Adams et al. 2013; Borisova et al. 2013). Full details on the NWSNAP methodology across all participating states and regions are provided by Mahler et al. (2013).

2.2 U.S. Southern Region survey

Nine states from the area defined as the Southern Region by USDA participated in the NWSNAP: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas. Surveys developed by extension leaders for the Southern Region were distributed on a state by state basis from 2008 to 2010. As described more fully below in section 2.6 (Dependent variables), these states were chosen as the focus of our present research due to a set of four relevant questions about water supply and climate change developed and specifically implemented within the Southern Region component of the NWSNAP. A total of 6812 surveys were mailed within the Southern Region, with 3163 completed surveys returned (response rate=46.4 %). State by state data of survey mailings and returns for the Southern Region are provided by Mahler et al. (2013).

2.3 Drought condition scores

We used datasets from the U.S. Drought Monitor (NDMC, NOAA, and USDA 2012) to derive temporally and spatially explicit drought condition scores for each respondent within the Southern Region NWSNAP dataset. The U.S. Drought Monitor is a weekly drought condition index developed and maintained by the National Drought Mitigation Center (NDMC), USDA, and the National Oceanic and Atmospheric Administration (NOAA). The index incorporates objective environmental indicators, such as soil moisture, daily stream flows, precipitation trends, reservoir and groundwater levels, vegetation health, and crop status reports, as well as more localized information obtained from climate experts throughout the country (Heim 2002). This information is synthesized into a five-tiered scale of drought condition that comprises the U.S. Drought Monitor: 0=Abnormally Dry; 1=Moderate Drought; 2=Severe Drought; 3=Extreme Drought; 4=Exceptional Drought. The Drought Monitor index defines drought condition as a deviation from normal rainfall, thereby normalizing the drought severity scale across regions with different precipitation regimes (Heim 2002). Archives of weekly GIS shapefile maps for U.S. Drought Monitor conditions across all states and territories extend back to January 2000. All files are freely available for download on the U.S. Drought Monitor website (NDMC, NOAA, and USDA 2012).

An ArcGIS 10 (ESRI 2011) workflow was used to derive short-term and long-term drought condition values for linkage to each survey respondent (Online Resource 1). Short-term drought condition was defined as the mean Drought Monitor scores in a 12-week window immediately before surveys were first mailed to the respondents. Long-term drought condition was defined as a period of five calendar years before the surveys were first mailed, excluding the 12-week period immediately before the survey. A listing of the specific Drought Monitor files that correspond to these definitions for each of the Southern Region state surveys is provided in Online Resource 2.

As shown in Online Resource 1, short-term and long-term drought condition metrics for each respondent were summed at the scale of 1 km^2 raster cells across the continental United States, and then averaged across the scale of each respondent's zip code boundary. The 3163 respondents were distributed across a total of 2024 unique zip codes. Although the temporal boundaries for the short-term (12-week) and long-term (5-year) drought condition metrics are somewhat arbitrary (i.e., other time intervals could have been applied), the study authors utilized their collective judgment as water resource and extension professionals to apply these periods based on the likely meaningfulness to the broader public. For example, the 5-year cut-off for long-term drought condition was based on the rationale that this period is long enough to smooth out inter-annual variations, but recent enough to assume that it covered conditions relevant to most respondents.

For short-term drought condition, we recognize that a more precise measure would be a specific record of respondents' zip-code-based drought condition at the time of survey completion. However, such spatio-temporally specific drought information was not originally recorded in NWSNAP database and post-marked envelopes were not available for subsequent assembly of such information. Consequently, the 12-week window immediately prior to the survey was chosen as a proxy estimate of the local short-term drought conditions condition experienced by respondents. We conservatively set the cut-off of the 12-week Drought Monitor period to the week directly before the survey mailings. This cut-off ensured that no Drought Monitor scores used in our analysis could include any climatological data occurring *after* any surveys were potentially completed by respondents.

The GIS workflow includes use of a background U.S. boundary file to define a new weekly attribute class of "No Drought" for areas that were not in a defined drought condition in any one of the individual Drought Monitor files (Online Resource 1). This step was necessary because the original weekly Drought Monitor files provide no spatial definition or associated attribute data for areas without a defined drought condition. To correct this issue, we obtained a background U.S. boundary shapefile from NDMC (C. Paulsen, personal communication, March 5 2012) to provide spatial definition across all weeks (i.e., as noted in the Union step of Online Resource 1). With this addition of a "No Drought" class, the following modified drought intensity scale was then applied: 0=No Drought; 1=Abnormally Dry; 2=Moderate Drought; 3=Severe Drought; 4=Extreme Drought; 5=Exceptional Drought.

While we do note that the U.S. Drought Monitor classification of "Abnormally Dry" will in most cases result in little to no major water resource impacts (Heim 2002), we chose to maintain a distinction between "Abnormally Dry" and "No Drought" for the purpose of maintaining differentiation between "normal/wet" (i.e., those areas not defined in any drought condition) and "dry" for all periods covered by our research. We also note that our study period included major rainfall flood events that affected Oklahoma and Texas in 2007 (Dong et al. 2011) and Georgia in 2009 (Shepherd et al. 2011), as well as the historically severe storm surge and flood events of Hurricane Katrina and Rita that afflicted coastal Louisiana, Mississippi, Alabama, and Texas in 2005 and 2006 (Day et al. 2007). Such flooding information is not captured by the Drought Monitor and is therefore not directly evaluated in this study. Map visualizations of the short-term and long-term drought condition measures by survey zip code are provided in Online Resource 3.

Drought conditions could not be calculated for 45 survey respondents with reported zip codes that were not spatially defined in the zip code GIS shapefile. These respondents were excluded from all analyses (revised N=3,114). While there was some positive correlation between the two drought condition scores across the surveyed zip codes (r=.348), this correlation is small enough to warrant inclusion of each measure as independent variables. The range of short-term drought condition (0 to ~4.0) was somewhat larger than for long-term drought condition (~0.1 to ~3.0), which can generally be explained by long-term drought condition being buffered by inter-annual variability. Areas of eastern Tennessee and south-eastern Texas showed extremely high levels of short-term drought during their survey period. However, short-term drought condition was generally lower than long-term drought condition across the region, with several states (Alabama, Arkansas, Mississippi, and Oklahoma) showing large areas with no drought conditions recorded during the 12-week period preceding their survey distributions.

2.4 Mean annual precipitation

The nine states of the U.S. Southern Region cut across a wide geographic area that has significant variation in annual precipitation patterns. Such differences in normal rainfall patterns may often have large impacts on public opinions about local water resources independent of those associated with drought (i.e., "less than normal" local rainfall) conditions (e.g., Lockett and McKenney 2002; Mahler et al. 2004; Routhe et al. 2005; Safi et al. 2012). To account for this effect, we used a publicly available shapefile (Daly and Taylor 2000; downloaded from http://geo.data.gov/geoportal/; Online Resource 5) to derive values of mean annual precipitation for inclusion as a separate predictor variable. Using a GIS workflow procedure similar to the one in Online Resource 1, this shapefile was transformed into a 1 km^2 raster grid file, with the grid values then summarized to a geographic mean at the zip code level. Although there was a negative correlation between mean annual precipitation and both short-term (r=-0.283) and long-term (r=-0.263) drought condition scores across survey zip codes, the magnitude of this correlation was not sufficient to rule out independent effects from annual precipitation.

2.5 Other independent variables

To test the strength of drought condition effects relative to other factors, we considered several additional independent variables derived from the survey dataset. These other variables included environmental ideology (original question image shown as Online Resource 5; question genesis described more fully by Mahler et al. 2008), community size, residency duration, gender, age, and education (original questions and distribution statistics for all socio-demographic variables provided in Online Resource 6; also described in Mahler et al. 2013). A wide body of literature indicates that such socio-demographic factors often provide a high level of predictive power about water resource and climate change opinions (Dietz et al. 2002; Palutikof et al 2004; Leiserowitz 2005; Semenza et al. 2008; Woudenburg et al. 2008; Raphael et al. 2009; Howe and Leiserowitz 2013), making it is important to include these for control and comparison with drought effects. Respondents were over-represented by males, higher in age, more urban and more highly educated as compared to the general public, but all socio-demographic sectors contained statistically significant samples (Mahler et al. 2013). Although differences among the suite of significant socio-demographic effects identified for different questions may have broader sociological interest (see, e.g., Hamilton et al. 2010), in the interest of brevity and research focus we do not discuss or interpret these results exhaustively in this paper.

2.6 Dependent variables

To test the hypothesis that local drought condition affects public opinions about water resources, we considered responses to four questions in the Southern Region survey that related to water resource and climate change issues. These questions utilized ordinal ranking scales to gauge respondent opinions about the following water resource and/or climate issues affecting their local area: 1) current water quantity; 2) future water quantity; 3) future drought likelihood; and 4) precipitation changes from global warming. The full question wording, ordinal scale coding, and raw attitudinal responses for these questions are summarized in Table 1.

2.7 Stepwise ordinal logistic regression

Effects of independent variables on respondent answers to the dependent variable questions were tested through stepwise ordinal logistic regression (logit) models run with the JMP 10.0

Table 1 Question wording, ordinal scale ranking, and response frequencies for dependent variables

Question [Abbreviated descriptor]	Choices [ordinal scale] {# of responses, %}
1) Do you regard water quantity (having enough water) as a problem in the area where you live? (Circle one answer) [Current water quantity]	a. Definitely not [1] {594, 18.8 %}
	b. Probably not [2] {1067, 33.7 %}
	c. I don't know [3] {371, 11.7 %}
	d. Probably [4] {561, 17.7 %}
	e. Definitely yes [5] {429, 13.6 %
	No response [N/A] {107, 3.4 %}
2) The likelihood of your area having enough water resources to meet all of its needs 10 years from now is: [Future water availability]	a. High (likely enough water) [1] {771, 24.4 %}
	b. Medium [2] {1170, 37.0 %}
	c. Low (likely not enough water) [3] {832, 26.3 %}
	d. No opinion [2] {273, 8.6 %}
	No response [N/A] {83, 2.6 %}
3) The likelihood of your area suffering from a prolonged drought is: [Future drought likelihood]	a. Increasing [3] {1362, 43.1 %}
	b. Decreasing [1] {168, 5.3 %}
	c. Staying the same [2] {1168, 36.9 %}
	d. No opinion [2] {341, 10.8 %}
	No response [N/A] {90, 2.8 %}
4) Do you think that the amount of rainfall in your area will change as a result of global warming? [Precipitation change from global warming]	a. Yes, a significant increase in rainfall [1] {150, 4.7 %}
	b. Yes, a slight increase in rainfall [2] {194, 6.1 %}
	c. No, no change in rainfall [3] {752, 23.8 %}
	d. Yes, a slight decrease in rainfall [4] {488, 15.4 %}
	e. Yes, a significant decrease in rainfall [5] {326, 10.3 %}
	f. I don't know [3] {1088, 34.4 %}
	No response [N/A] {131, 4.1 %}

statistical package (Sall et al. 2007). As noted in Table 1, “No opinion” answers for questions 2), 3), and 4) were pooled into the respective “neutral” classification (i.e., Medium; Staying the Same; or No, no change in rainfall). A similar procedure was unnecessary for water quantity because the “I don’t know” response provided the only neutral option within the ordinal scale. Comparison of logit models fit through the pooled approach with those excluding “No opinion” indicated only minor relative effect differences that did not affect interpretation of the overall results. Because pooled models have the advantage of higher respondent numbers, in the interest of brevity we do not report the non-pooled results in this manuscript.

We applied a stepwise rule of minimizing Bayesian information criterion (BIC), a conservative penalty function often applied to ordinal logistic regression models with relatively large sample sizes (Hastie et al. 2009), for inclusion of independent variables into the final model runs. As such, independent variables that resulted in an increase of BIC when added into the model were rejected from consideration. Final model runs were fit using the respondents that validly marked the dependent variable question and all independent variables selected in the stepwise procedure. The significance of independent variable effects was assessed through likelihood ratio chi-square statistics (Sall et al. 2007).

To facilitate relative comparison of estimate coefficients among each of the independent variables, the values of all continuous variables (i.e., short-term drought condition, long-term drought condition, mean annual precipitation, environmental ideology, and age) were normalized such that minimum values equaled -1 and maximum values equaled 1. This normalization scale was chosen because it corresponds to the default numeric values applied to binned nominal variables. Consequently, comparative strength of independent variable effects can be directly compared across all considered variables based on the relative magnitude of estimate coefficients and associated standard errors. The disadvantage of this normalization procedure is that it prevents formal interpretation of estimate coefficient meanings for the continuous variables. However, we deemed this loss acceptable because formal interpretation of effect coefficients, as defined in terms of log odds ratios, is non-intuitive for continuous variables (see, e.g., Harrell 2001) and deemed as unnecessary to meet the goals of our research.

3 Results

3.1 Drought condition effects

All model results (Tables 2 and 3) supported the hypothesis that local drought conditions would be a significant predictor of respondents’ level of concern for water supplies and water-related climate change risks (full model $p<0.001$). Long-term (i.e., 5-year) drought condition was identified as a highly significant ($p<0.001$) predictor for both water supply questions (i.e., current water quantity and future water availability), and showed a somewhat less strong, but still significant ($p<0.01$), effect on opinions about future drought likelihood (Table 2). By contrast, short-term (i.e., 12-week) drought condition was identified as a highly significant ($p<0.001$) predictor for the two climate change-related questions (i.e., future drought risk and precipitation changes from global warming) summarized in Table 3. All drought condition effects moved in the expected direction (-) of higher drought condition being associated with greater concern about decreased local water supplies and/or increased local drought risk.

Table 2 Logit model results of independent variable effects on opinions about local water quantity (Current Water Quantity) and future water availability (Future Water Availability)

	Current Water Quantity		Future Water Availability	
	Estimate (Std error)	L-R chi square	Estimate (Std error)	L-R chi square
Short-term drought severity	–	–	–	–
Long-term drought severity	−0.839 (0.104)	64.00***	−0.671 (0.105)	40.80***
Mean annual precipitation	0.757 (0.119)	39.56***	0.451 (0.121)	14.25***
Environmental ideology	−0.417 (0.111)	13.57***	−0.689 (0.112)	37.13***
Community size[1]	−0.118 (0.037)	10.18**	–	–
Residency duration[2]	–	–	0.274 (0.046)	36.84***
Education	–	–	–	–
Gender[3]	–	–	0.307 (0.078)	15.72***
Age	–	–	–	–
N (final model)	2510		2672	
p (full model)	***		***	

Likelihood Ratio Significance p<0.05=*; p<0.01=**; p<0.001=***

[1] Community size: [1 =>100,000; 25,000–100,000], [−1=7000–25,000; 3500–7000; < 3500]

[2] Residency duration: [1=All my life], [−1=>10 years; 5–9 years; < 5 years]

[3] Gender: [1=Male], [−1=Female]

3.2 Precipitation effects

Mean annual precipitation showed a highly significant (p<0.001) effect on the current water quantity model, with only long-term drought condition showing a stronger effect in the model. Precipitation was also shown as a significant predictor (p<0.001) for future water availability. Precipitation effects for both of these models moved in the expected direction (+) of lower mean annual precipitation being associated with increased levels of respondent concern about the adequacy of local water supplies. Precipitation was not identified as a significant predictor of opinions about future drought risk or precipitation changes from global warming.

3.3 Socio-demographic effects

The environmental ideology of respondents showed a highly significant (p<0.001) effect for every model run and in all cases showed the highest estimate effect among the socio-demographic variables. As expected (e.g., Jorgensen et al. 2009; Howe and Leiserowitz 2013), the direction (-) of these effects indicated that that those respondents who favored higher levels of environmental protection were also more likely to show greater concern about local water supplies and local drought risks. All other socio-demographic variables emerged as

Table 3 Logit model results of relative independent variable effects on opinions about local drought occurrence (Drought Risk) and precipitation effects due to global warming (Global Warming)

	Future Drought Likelihood		Precipitation Changes from Global Warming	
	Estimate (Std Error)	L-R Chi Square	Estimate (Std Error)	L-R Chi Square
Short-term drought severity	−0.741 (0.101)	56.57***	−0.511 (0.086)	34.07***
Long-term drought severity	−0.361 (0.114)	9.99**	–	–
Mean annual precipitation	–	–	–	–
Environmental ideology	−0.631 (0.118)	29.17***	−0.599 (0.117)	26.39***
Community size	–	–	–	–
Residency duration	–	–	–	–
Education[1]	−0.149 (0.046)	10.34**	–	–
Education[2]	–	–	−0.120 (0.038)	9.88**
Gender	–	–	–	–
Age	−0.332 (0.102)	10.62**	–	–
N (final model)	2691		2689	
p (full model)	***		***	

Likelihood Ratio Significance $p<0.05$=*; $p<0.01$=**; $p<0.001$=***

[1] Education: [1=Advanced college degree], [−1=College graduate; Some college; High school graduate; Less than high school or some high school]

[2] Education: [1=Advanced college degree; College graduate], [−1=Some college; High school graduate; Less than high school or some high school]

significant predictors of opinions in at least one model, but in all cases had estimate effects lower than environmental ideology and at least one of the drought condition categories.

4 Discussion

4.1 Long-term climate effects on water supply opinions

We found that respondents' opinions toward both water supply questions (current water quantity and future water availability) were very strongly affected by two *long-term* environmental variables: long-term drought condition and, to a lesser extent, mean annual precipitation. Short-term drought condition, by contrast, showed no significant independent effect in the water supply models. Taken together, these findings suggest that worries about water supply were strongly influenced by an integration of drought condition as experienced over an extended multi-year period, were not significantly exacerbated by short-term drought extremes, and were not alleviated by short-term deviations toward wetter conditions.

These patterns are generally consistent with the framing of water supply as a core socio-economic concern that, consequently, tends to engender opinions formed through a synthesis of long-term experiences (see, e.g., Gleick et al. 2006). It is, for example, logical that those respondents who live in areas with lower levels of annual precipitation would tend to express greater worries about water supply, as the water supply in drier regions tends to be more complicated, expensive, and insecure than in areas with plentiful rainfall. The highly significant influence of long-term drought condition would appear to have a similarly straightforward explanation, particularly because the 5-year time windows included several severe drought events across a number of Southern Region states. Water supply concerns associated with these drought events in some cases prompted initiation of major municipal water restrictions, water utility rate increases, comprehensive water supply planning efforts, and other aggressive conservation strategies (Knutson 2008; Manuel 2008; Feldman 2009; Mansur and Olmstead 2012). It could be speculated that such consequences, which were highly visible and had substantial socio-economic impacts on local communities (Hightower and Pierce 2008; Dow 2010), tended to fix individual opinions about water supply in the aftermath of persistent drought events. The highly significant importance of residency duration in the future water availability model, with long-term residents (i.e., All my life and >10 years categories) showing less concern than those with less residency duration, may further suggest the importance of long-term local experience on attitude formation. For example, previous research indicates that long-term residents generally tend to be more anthropocentric (Vaske et al. 2001) and likely to believe that human ingenuity will effectively solve most environmental problems (Heath and Gifford 2006). This may be broadly consistent with individuals with longer local residency having experience with past local water supply concerns being remedied through new technologies and supply sources, perhaps thereby leading them to be less concerned that future problems will not be similarly solved.

4.2 Short-term drought effects on climate change opinions

In contrast to the water supply questions, we found that respondents' opinions toward the two future climate change questions (future drought likelihood and precipitation changes from global warming) were much more strongly affected by *short-term* drought condition. These results suggest that higher levels of short-term drought condition made respondents' more likely to believe that future risks from severe drought were increasing and that global warming was likely to result in less future rainfall.

To our knowledge, the specific documentation of a highly significant relationship between short-term drought condition and public opinions about water-related climate change is also a novel research finding. However, this result is generally consistent with previous work indicating that individual opinions and expressed concern about climate change and global warming are significantly influenced by short-term environmental cues, such as the ambient temperature on the day of survey (Joireman et al. 2010; Li et al. 2011; Weber and Stern 2011) and experimental manipulations in the condition of indoor foliage (Gueguen 2012). The significant importance of environmental ideology and educational attainment (i.e., more concern associated with higher education levels) for both climate change models is also consistent with other previous studies into public opinions about climate change issues (e.g., Leisorowitz 2005; Semenza et al. 2008; Woudenburg et al. 2008). The lack of importance of the precipitation variable for opinions related to climate change is also similar to the finding by Safi et al. (2012) that conditions of local water stress, which included a metric of differences in relative annual precipitation across local areas, had no significant effect on respondents' opinions about the significance of climate change.

The apparently dominant reliance on recent cues suggests that respondents framed climate change as an abstract and peripheral problem, as significant integration of related long-term experiences such as persistent drought and living in an area of low annual precipitation would be expected if the issue was of core concern (Weber and Stern 2011). The significant predictor variables for opinions about precipitation changes from global warming provide little apparent deviation in this general pattern, particularly when interpreted alongside the comparatively large percentage (34.4 %) of "I don't know" responses (Table 1) — a result that may reflect a high degree of ideological discomfort and/or ambivalence about the concept of global warming. However, the significance of both age and long-term drought condition for opinions about future drought likelihood model may suggest a somewhat more complex interaction between short-term and long-term experience on this question.

The age effect in the future drought likelihood model is noteworthy because it indicates that older individuals were significantly more likely to believe that local drought risk was increasing. This result seemingly runs counter to the general tendency of older individuals to express progressively less concern about environmental issues (e.g., Mohai and Twight 1987; Zelezny et al. 2000), as well as previous research indicating that older farmers in the U.S. Great Plains region were less likely to believe that droughts were occurring more frequently due to climate change (Diggs 1991). However, climate records generally indicate that drought frequency and severity have measurably increased across much of the Southern Region over recent decades (Wang et al. 2010). This worsening of regional drought condition over time provides a point of contrast to the Great Plains research of Diggs (1991), which included a number of older respondents who noted experience of droughts from the 1930s Dust Bowl period that were historically devastating to the Great Plain region. Diggs (1991) speculates that the age results in his study may be related due to this longer pool of experience with wet and dry climate cycles, including the Dust Bowl conditions that are still recognized as the worst U.S. drought experienced over at least the past 100 years (Heim 2002). We speculate that the different opinions of older respondents in our survey results could be similarly reflecting a pool of lifetime experiences, but which in our case include an experiential time horizon in which droughts may have become measurably more frequent and severe across the sample population. However, further research is required to test this suggestion directly.

Even with these nuances, the identification of short-term drought condition as the most significant predictor for opinions about both future drought likelihood and precipitation changes from global provides a clear point of contrast to the water supply models. Moreover, these highly significant effects were detected through a short-term drought condition metric that was relatively imprecise (i.e., averaged over 12 weeks). For reasons noted above, we recommend that future surveys of this type develop a more exact short-term drought condition metric for each individual respondent, rather than rely upon the temporally imprecise post hoc calculations developed here due to lack of more specific information about survey return dates. A more straightforward and precise metric would be to record the Drought Monitor score for each respondent's address on the date immediately preceding the postmark of the returned survey. The Drought Monitor is now also regularly including additional information about the duration of droughts currently being experienced in local areas (S = short-term drought; L = long-term drought). While not available for our study time period, this duration information might also be usefully incorporated into future survey research studies.

5 Summary and conclusions

The findings of our study provide strong support for the hypothesis that local drought conditions have highly significant impacts on public opinions about related water supply and climate change issues. From an applied perspective of water conservation outreach and extension, these results strongly suggest that local drought condition data should be considered in the course of programmatic evaluations that utilize longitudinal surveys of public opinions about water resources and climate change. The methods and results also indicate that the U.S. Drought Monitor's freely available datasets provide a ready means for quantifying local drought condition and spatio-temporally linking these measures to survey responses.

The study's results also provide other potentially useful insights for water conservation and climate change outreach programs. For example, the finding that the general public tends to be much more concerned about water resources and climate change during times of extreme drought supports the contention that such events provide an opportunity for outreach programs to more effectively influence opinions and change behaviors (Jensen 1996; Cohen et al. 2006). At the same time, the tendency for public concern about water to ebb in times of higher rainfall may also suggest that consistent outreach messages about climate variability and associated local water challenge may actually be most needed during relatively wet periods. Although such "countercyclical" messaging will likely result in less adoption of recommended practices as compared to drought periods, consistent reinforcement of appropriate water conservation strategies may be necessary to facilitate adoption of these practices as permanent behavioral "norms," rather than temporary drought mitigation strategies.

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