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Examining Climate Emotions That Accompany Personal Experiences Of Climate Change: A Dynamic Network Analysis

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Badges for Good Research Practices: Code. Data. Diversity Statement. Materials. Preregistration.

Abstract

Climate change elicits emotional responses for many individuals — especially those who have personally experienced its impacts. While it is widely accepted that climate emotions co-occur at one time point and change over time, little is known about the temporal dynamics among climate emotions (that is, their relations over time) and how those dynamics differ based on personal experiences of climate change. In this study, we applied a multivariate multilevel model to five-wave panel data collected from 3,936 American adults to examine the dynamics among 11 climate emotions that accompany personal experiences of climate change. We observed inhibitory and excitatory dynamics between different pairs of climate emotions, with some emotions (like pride) exhibiting greater sensitivity to others and some emotions (like anxiety) appearing more central within the emotional network. In general, participants with fewer personal experiences of climate change exhibited more interdependence among their climate emotions than those with more. Taken together, our results suggest that climate emotions, which underpin both climate action and

well-being, change interdependently and that individuals' lived experiences of climate change shape how their entire climate emotion network changes over time.

Keywords

climate emotions, personal experiences of climate change, multivariate, longitudinal, dynamic network analysis

Non-Technical Summary

Background

Climate change elicits emotions for many people, especially those who have personally experienced its impacts.

Why was this study done?

People often feel multiple climate emotions at the same time, all of which may change over days, months, and years. However, we do not yet know (1) how climate emotions change in response to one another and (2) whether those relationships differ for people with different personal experiences of climate change.

What did the researchers do and find?

We asked American adults about their climate emotions five times over eight months. We found that climate emotions change interdependently and that there is more interdependence among climate emotions for people with fewer personal experiences of climate change than those with more personal experiences.

What do these findings mean?

Climate emotions underpin people's climate action and well-being. As a result, a better understanding of climate emotion dynamics can help inform interventions like risk communication and climate-aware therapy and pedagogies. Understanding how personal experiences factor into climate emotion dynamics is also becoming increasingly important as more and more people are exposed to the impacts of climate change.

Highlights

- Climate emotions at one point in time are related to other climate emotions at a subsequent point in time.
- Some pairs of climate emotions exhibit excitatory dynamics while others exhibit inhibitory dynamics.
- Dynamics among climate emotion varied for people with different personal experiences of climate change.

Climate change elicits emotions ("climate emotions") for many individuals, which shape their climate action and well-being (Clayton & Ogunbode, 2023; Hickman et al., 2021; Pihkala, 2022a; Smith & Leiserowitz, 2014; Stanley et al., 2021; van Valkengoed & Steg, 2019). Though prior work has mostly examined climate emotions as singular and separable phenomena at one time point, recent evidence suggests that climate emotions co-occur (Hickman et al., 2021; Wang et al., 2018), change over time (Chan et al., 2024; McBride et al., 2021; Sciberras & Fernando, 2022), and perhaps even influence each other over time (Contreras et al., 2024). In this exploratory study, we examine the temporal dynamics of climate emotions and whether those dynamics are moderated by personal experiences of climate change.

Overview of Climate Emotions

Just as eco-emotions emerge from appraisals about the natural environment (Kals & Müller, 2012), climate emotions emerge from appraisals about climate change. Building on taxonomies of eco-emotions (e.g., Böhm, 2003; Landmann, 2020), Pihkala (2022b) categorizes climate emotions as those related to "surprise", "threat", "sadness", "anxiety", "depression", "guilt and shame", "indignation", "disgust", "anger", "envy", "hostility", and "positive emotions".

To examine the temporal dynamics among climate emotions, we focus on 11 emotions from Pihkala's (2022b) taxonomy that provide broad coverage across the dimensions of valence, arousal, focus on the self or others, function, and temporal orientations: anger, anxiety, fear, sadness, guilt, betrayal, hope, pride, determination, compassion, and gratitude. A growing body of research has examined these particular climate emotions. For instance, climate *anger* has been reported by youth and environmentalists alike (Hickman et al., 2021; Voşki et al., 2023) and is often attributed to the anthropogenic nature of climate change (Gregersen et al., 2023). Climate *anxiety* and *fear* are distinct but frequently co-occurring, with anxiety emerging in response to an uncertain, future-oriented threat and fear emerging in response to a direct, immediate threat (Clayton, 2020; Ojala et al., 2021; Pihkala, 2020). Climate *sadness* occurs in response to losses caused by a changing climate (Cunsolo et al., 2020). Climate *guilt* and *pride* are social emotions that may regulate one's climate-related behaviors (Jacquet, 2017; Shipley & van Riper, 2022). Climate *betrayal* is a form of moral outrage, manifesting when one (often youth) perceives injustice in the (in)actions of others, such as previous generations or governments (Hickman et al., 2021; Jones & Davison, 2021).

Pihkala's (2022b) category of positive emotions encompasses climate *hope*, *determination*, *compassion*, and *gratitude*. Climate *hope* emerges in response to desirable, future-oriented outcomes (Geiger et al., 2023), which may enable problem-focused coping (Kleres & Wettergren, 2017) or emotion-focused coping (van Zomeren et al., 2019). Climate *determination* — defined as strong motivation and willingness (Pihkala, 2022b) — similarly correlates with climate-related behaviors (Verplanken et al., 2020). While climate

compassion is an other-suffering emotion centered on care for people and places affected by climate change (Lu & Schuldt, 2016), climate *gratitude* is an other-praising emotion that tends to arise from collective climate action (Marczak et al., 2023). In sum, many types of emotions are elicited by climate change, with implications for climate action and well-being.

Co-Occurrence and Change in Climate Emotions

Importantly, individuals experience multiple climate emotions simultaneously. Of 10,000 youth surveyed across ten countries, over 50% reported feeling sad, anxious, angry, *and* guilty about climate change (Hickman et al., 2021). Similarly, Wang and colleagues (2018) described the interplay of 13 co-occurring climate emotions — anger, irritation, fear, despair, powerlessness, guilt, shame, apathy, boredom, confusion, hope, joy, and excitement — experienced by scientists, students, and the general public. In line with emotion researchers' arguments (e.g., Chapman et al., 2017; Zeelenberg et al., 2008), these findings suggest that studying emotions separately paints only a partial picture. Because climate emotions co-occur, it is useful to examine them as a *network* wherein experiencing one climate emotion may give rise to experiencing other climate emotions.

Furthermore, climate emotions change over time. Some have speculated that climate emotions change at different rates, with understanding-related emotions like anxiety persisting longer than action-oriented emotions like compassion (Georgiou & Van Lange, 2026). Others have proposed that climate emotions develop as individuals move through stages of action, grief, and distancing in response to climate change (Pihkala, 2022a). Yet few studies have empirically examined these changes over time. As notable exceptions, McBride and colleagues (2021) and Chan and colleagues (2024) each observed slight increases in climate concern and climate anxiety, respectively, in two-wave panel data. Additionally, Sciberras and Fernando (2022) identified six distinct climate worry trajectories in Australian adolescents — revealing that climate worry changes over time and in different ways for different people. These studies of different climate emotions (concern, anxiety, and worry) in different populations (New Zealand adults, American adults, and Australian adolescents) at different timescales (one year, four months, and eight years) all suggest that climate emotions change over time.

Dynamic Network Analysis

Examining climate emotions as a dynamic network, where they may both co-occur and change over time, can improve our understanding of their interdependence. In dynamic systems parlance, interdependencies among constructs may be *inhibitory* or *excitatory*. Inhibitatory dynamics occur when higher levels of one construct produce lower levels of other constructs at subsequent time points; whereas excitatory dynamics occur when higher levels of one construct produce higher levels of other constructs at subsequent

time points (Kuppens & Verduyn, 2017). Integrating principles from dynamic systems into the study of climate emotions, we examine inhibitory and excitatory dynamics among climate emotions using a dynamic network analysis.

Dynamic network analysis of multivariate longitudinal data — increasingly used in psychology (e.g., Borsboom et al., 2021) — can reveal how climate emotions change interdependently in everyday life. For example, this approach has shown that general emotions with the same valence (e.g., anger and sadness, happiness and relaxation) excite each other over time, while those with an opposite valence (e.g., anger and relaxation, sadness and happiness) inhibit each other (Pe & Kuppens, 2012). This approach has also shown that emotion dynamics manifest differently across individuals (Yang et al., 2019). To our knowledge, only one study has applied a dynamic network approach to climate emotions. In their 60-day experience sampling study of Belgian adults, Contreras and colleagues (2024) found that higher daily levels of climate anger, anxiety, and sadness each predict higher levels of all three emotions the following day, indicating excitatory dynamics. We extend this prior work by examining the excitatory and inhibitory dynamics of 11 climate emotions (both positive and negative) over eight months.

Personal Experiences of Climate Change

If climate emotions change interdependently, as general emotions do (Pe & Kuppens, 2012), a next question is whether their dynamics vary across individuals, like those of general emotions (Yang et al., 2019). Numerous studies have found that individuals' experiences of climate emotions are shaped by their *personal experiences of climate change* — that is, their perception of having been personally impacted by climate change (Akerlof et al., 2013; Demski et al., 2017; Demuth et al., 2016). Such perceptions may influence climate emotions more than objective measures of exposure due to psychological factors like subjective attribution and belief in climate change (e.g., Andrews et al., 2025; Xia et al., 2022). Regarding *levels* of climate emotions, a study of over 15,000 youth in the United States found that self-reported prior experiences of extreme weather events are associated with greater climate worry and anxiety (Lewandowski et al., 2024). Regarding *dynamics* among climate emotions, an individual's personal experiences of climate change could strengthen excitatory dynamics by heightening their sensitivity to climate change; alternatively, such experiences could strengthen inhibitory dynamics by prompting their regulation of climate emotions. As more people are exposed to the impacts of climate change, understanding how personal experiences factor into climate emotion dynamics is critical for promoting climate action and well-being.

The Present Study

Prior research suggests that individuals experience co-occurring, changing, and interdependent climate emotions. In this exploratory study, we leverage a dynamic network

analysis to unpack the known complexity of climate emotions. Drawing from the taxonomy of climate emotions (Pihkala, 2022b) and dynamic systems principles, we address the following research questions:

RQ1: What are the temporal dynamics among individuals' climate emotions?
RQ2: How do personal experiences of climate change moderate the dynamics among individuals' climate emotions?

We fit a multivariate multilevel model to five-wave panel data collected from 3,936 adults living in the United States at seven-week intervals to examine whether dynamics among 11 climate emotions are inhibitory or excitatory (RQ1) and whether personal experiences of climate change are associated with different climate emotion dynamics across individuals (RQ2).

Method

Participants and Procedures

Longitudinal data were collected from 3,936 adults (56.65% female), aged 18 to 89 years (M = 47.52, SD = 14.13), living in the United States who completed online surveys at seven-week intervals (each available for 14 days; Ng et al., 2024). At the outset of the study in June 2024, a nationally representative sample — with respect to gender, age, race and ethnicity, annual household income, education, metropolitan status, region, political partisanship, and recalled 2020 presidential election vote — of 6,000 adults was recruited by Verasight using a combination of probability and nonprobability methods. After providing informed consent in accordance with Protocol #23159 approved by Indiana University, those N = 6,000 participants reported their personal experiences of climate change, climate emotions, and socio-demographic characteristics in a Wave 1 survey (July 2024). Upon re-contact, N = 3,954 of these participants completed a Wave 2 survey (August–September 2024), N = 2,535 completed a Wave 3 survey (October–November 2024), N = 1,855 completed a Wave 4 survey (December 2024), and N = 1,150 completed a Wave 5 survey (January–February 2025) about their climate emotions (see Ng et al., 2024; Supplementary Table S1). Participants were compensated $1 for completing the first survey (~15–20 minutes) and $2 for each subsequent survey (~10–15 minutes). Given our interest in temporal dynamics among climate emotions, our analysis focused on 13,385 surveys provided by 3,936 participants who completed at least two surveys. Attrition analyses indicated that participants who completed multiple surveys were somewhat older (d = 0.31), White, male, and more affiliated with Democratic, Republican, or Independent political parties than the initial nationally representative sample (see Ng et al., 2024; Supplementary Tables S2–S9). Socio-demographic characteristics of participants are shown in Table 1.

Table 1

Socio-Demographic Characteristics of Participants

Characteristic	*N*	%
Gender		
Female	2,229	56.65%
Male	1,684	42.79%
Other	23	0.58%
Age		
18 to 24 years	154	3.93%
25 to 34 years	598	15.25%
35 to 44 years	1,052	26.82%
45 to 54 years	863	22.00%
55 to 64 years	682	17.39%
65 to 74 years	472	12.03%
75 years or older	101	2.58%
Race and ethnicity		
Black	485	12.32%
Hispanic	633	16.08%
White	2,553	64.89%
Other	265	6.73%
Annual household income		
Under $50,000	1,563	39.71%
Over $50,000	2,370	60.23%
Declined to answer	3	0.08%
Education		
High school or less	1,116	28.37%
Some college or 2-year degree	1,337	33.98%
4-year or post-graduate degree	1,483	37.66%
Metropolitan status		
Metropolitan	3,325	84.49%
Non-metropolitan	566	14.39%
Declined to answer	45	1.14%
Region		
Midwest	855	21.73%
Northeast	643	16.34%
South	1,568	39.85%
West	828	21.04%
Declined to answer	42	1.07%
Political partisanship		
Democrat	1,551	39.41%
Independent	922	23.43%
Republican	1,094	27.80%
Other or none	366	9.30%
Declined to answer	3	0.08%

Note. N = 3,936. Age categories blur participants' exact age to protect privacy.

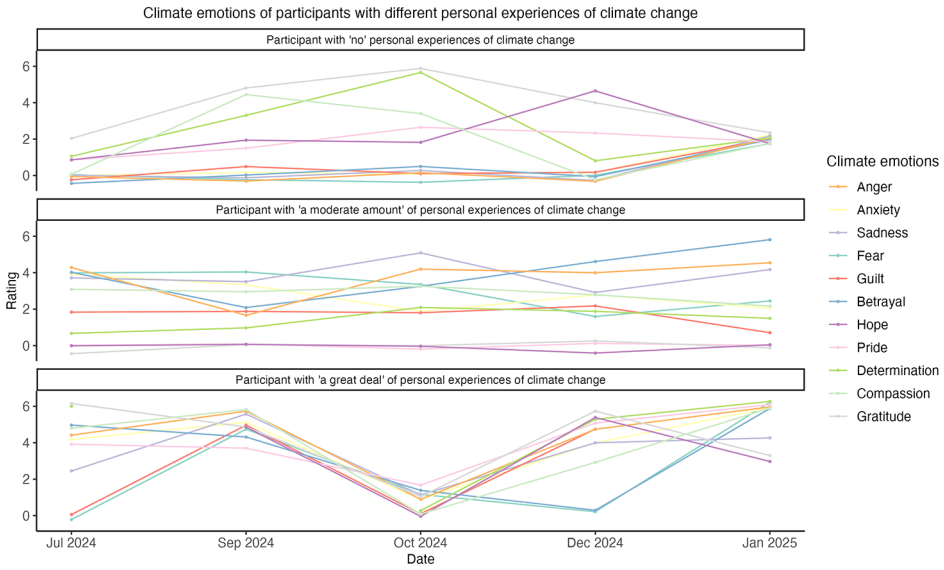
Measures

Climate Emotions (Waves 1–5)

In each survey wave, participants responded to the item: "To what extent have you experienced each of the following emotions when thinking about climate change in the last week?" for 11 discrete emotions (angry, anxious, sad, afraid, guilty, betrayed, hopeful, proud, determined, compassionate, and grateful) using verbal response options "Not at all", "A little", "Somewhat", "A moderate amount", "A considerable amount", "A lot", and "A great deal". Verbal responses were coded as numeric values ranging from 0 ("Not at all") to 6 ("A great deal"). Changes in climate emotions observed over eight months for three participants are shown in Figure 1.

Figure 1

Changes in Climate Emotions Observed Over Eight Months for Three Randomly Selected Participants With Different Levels of Personal Experiences of Climate Change



Note. Intraindividual variability in climate emotions (colors) is shown for three participants: one with "no" personal experiences of climate change (top row), one with "a moderate amount" of personal experiences of climate change (middle row), and one with "a great deal" of personal experiences of climate change (bottom row). Colored lines indicate how each of 11 climate emotions changed across five waves of data obtained at seven-week intervals between July 2024 and February 2025.

Personal Experiences of Climate Change (Waves 1 and 3)

In the first and third wave, participants responded to the item: "How much have you personally experienced the effects of climate change (e.g., extreme heat, flooding, drought,

storms)?" with verbal response options "Not at all", "A little", "Somewhat", "A moderate amount", "A considerable amount", "A lot", and "A great deal". Verbal responses were coded as numeric values ranging from 0 ("Not at all") to 6 ("A great deal"). To improve the stability of the measure, a personal experiences of climate change index was calculated as the average of participants' responses at Wave 1 and Wave 3.

Time (Waves 1–5)

Time was operationalized as survey wave number, with each unit of time corresponding to change over seven weeks, and centered at Wave 3.

Data Analysis

Analyses were preregistered in August 2024 before the data were fully collected (Ng et al., 2024). We proposed an exploratory study wherein we would estimate separate multilevel vector autoregression models (Bringmann et al., 2013), using the *mlVAR* package in R, for two groups of participants that reported having few or many personal experiences of climate change. However, inspection of the data revealed that the *personal experiences of climate change* variable was relatively normally distributed and that the initially planned *mlVAR* implementation of the model did not converge with our data (potentially due to the low number of repeated observations or multicollinearity). To better accommodate the properties of the data, we pivoted to a Bayesian modeling framework that allowed us to estimate the same set of equations described in the preregistration analysis plan with a more robust procedure, use the personal experiences of climate change variable as a continuous moderator, and incorporate survey weights to improve representativeness.

Data Preparation

Following best practices for longitudinal data analysis, each climate emotion score for each participant was separated into a between-person variable (a person-level mean indicating each participant's "trait" tendency to experience each climate emotion) and a within-person variable (an occasion-level deviation from each participant's person-level mean indicating their "state" experience of each climate emotion) (Bolger & Laurenceau, 2013). This process of person-mean centering is critical for isolating and studying time-varying phenomena. Setting the between-person components aside, we focused our analysis on within-person dynamics among climate emotions while essentially controlling for between-person differences in the baseline levels of each climate emotion. For ease of interpretation, the *personal experiences of climate change* variable was sample-centered and standardized ($M = 0$, $SD = 1$) prior to analysis.

Data Analysis

To analyze the data, we leveraged a dynamic network approach. Rather than estimating how predictor variables (all climate emotions at time_{t-1}) relate to a single outcome

variable (one climate emotion at $time_t$), we fit a multivariate multilevel model that simultaneously estimated how predictor variables (all climate emotions at $time_{t-1}$) relate to multiple outcome variables (all climate emotions at $time_t$). The contemporaneous and dynamic relations among 11 climate emotion states were examined using 11 coupled equations of the form:

$$
\begin{aligned}
(1)\quad & Emo\_state_{(t,i)} = \beta_{Emo0} + \beta_{Emo1}(Anger\_state_{(t-1,i)}) + \beta_{Emo2}(Anxiety\_state_{(t-1,i)}) + \\
& \beta_{Emo3}(Sadness\_state_{(t-1,i)}) + \beta_{Emo4}(Fear\_state_{(t-1,i)}) + \beta_{Emo5}(Guilt\_state_{(t-1,i)}) + \\
& \beta_{Emo6}(Betrayal\_state_{(t-1,i)}) + \beta_{Emo7}(Hope\_state_{(t-1,i)}) + \beta_{Emo8}(Pride\_state_{(t-1,i)}) + \\
& \beta_{Emo9}(Determination\_state_{(t-1,i)}) + \beta_{Emo10}(Compassion\_state_{(t-1,i)}) + \\
& \beta_{Emo11}(Gratitude\_state_{(t-1,i)}) + \beta_{Emo12}(Time_{(t,i)}) + \beta_{Emo13}(Experiences_i) + \\
& \beta_{Emo14}(Anger\_state_{(t-1,i)})(Experiences_i) + \beta_{Emo15}(Anxiety\_state_{(t-1,i)})(Experiences_i) + \\
& \beta_{Emo16}(Sadness\_state_{(t-1,i)})(Experiences_i) + \beta_{Emo17}(Fear\_state_{(t-1,i)})(Experiences_i) + \\
& \beta_{Emo18}(Guilt\_state_{(t-1,i)})(Experiences_i) + \beta_{Emo19}(Betrayal\_state_{(t-1,i)})(Experiences_i) + \\
& \beta_{Emo20}(Hope\_state_{(t-1,i)})(Experiences_i) + \beta_{Emo21}(Pride\_state_{(t-1,i)})(Experiences_i) + \\
& \beta_{Emo22}(Determination\_state_{(t-1,i)})(Experiences_i) + \\
& \beta_{Emo23}(Compassion\_state_{(t-1,i)})(Experiences_i) + \\
& \beta_{Emo24}(Gratitude\_state_{(t-1,i)})(Experiences_i) + u_{Emo(i)} + e_{Emo(t,i)}
\end{aligned}
$$

where each of the 11 climate emotion state variables recorded at wave t for individual i, $Emo\_state_{(t,i)}$, is modeled as a function of an emotion-specific intercept (β_{Emo0}) that should be near zero given person-mean centering, all 11 climate emotion state scores from the prior wave, (e.g., $Anger\_state_{(t-1,i)}$, $Anxiety\_state_{(t-1,i)}$), a time variable that controls for linear trends ($Time_{(t,i)}$), the personal experiences of climate change variable ($Experiences_i$), interactions between each of the 11 climate emotion state scores from the prior wave and the personal experiences of climate change variable, e.g., ($Anger\_state_{(t-1,i)}$)($Experiences_i$), random effects capturing individual differences in the intercept ($u_{Emo(i)}$) that are multivariate normally distributed and may be correlated across the 11 equations, and wave-specific residuals ($e_{Emo(t,i)}$) that are also assumed multivariate normally distributed and may be correlated across the 11 equations. Together, the 11 coupled equations constitute a multivariate multilevel model where the βs indicate the prototypical participant's dynamics among climate emotions and linear time effects and where correlations among residuals indicate the prototypical participant's contemporaneous relations among the 11 climate emotions.

Bayesian Estimation

Models were estimated in R (Version 4.2.3) using the *brms* (Version 2.22.0; Bürkner et al., 2024) and *bayestestR* (Version 0.13.2; Makowski et al., 2024) packages with Markov Chain Monte Carlo (MCMC) sampling and weakly informative priors (Ng et al., 2024). Observation-level weights calculated by Verasight were incorporated to approximate the initial sampling frame. Missing or incomplete data were treated as missing completely at random by the Bayesian models. Inspections of R-hat values, effective sample sizes,

posterior distributions, and posterior predictive checks all suggested the MCMC algorithms had converged. Substantive inferences were based on the posterior distributions of each parameter using 95% credible intervals and probability of direction. Results were visualized using the *circlize* package (Version 0.4.16; Gu, 2024).

Results

Between-person and within-person descriptive statistics for and correlations among climate emotions are shown in Table 2. In general, participants reported low levels of each climate emotion (M = 1.32 to 2.03). Between-person and within-person correlations among climate emotions were all positive (between-person: r = .26 to .88; within-person: r = .08 to .63), indicating that higher levels of any climate emotion were accompanied by higher levels of all other climate emotions. Climate emotions thus do not organize along the positive–negative valence dimension typically used to describe general emotions. Having more personal experiences of climate change was also accompanied by higher levels of all climate emotions (r = .38 to .54).

Table 2

Between-Person and Within-Person Descriptive Statistics and Correlations Among Study Variables

	Descriptives			Correlations											
Variable	M_b	SD_b	SD_w	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Anger	1.83	1.57	1.04	—	*0.46*	*0.61*	*0.56*	*0.39*	*0.42*	*0.12*	*0.13*	*0.27*	*0.25*	*0.12*	—
2. Anxiety	1.92	1.61	1.01	**0.79**	—	*0.50*	*0.52*	*0.39*	*0.39*	*0.15*	*0.21*	*0.35*	*0.35*	*0.22*	—
3. Sadness	1.94	1.63	1.04	**0.86**	**0.82**	—	*0.63*	*0.45*	*0.39*	*0.12*	*0.10*	*0.27*	*0.29*	*0.12*	—
4. Fear	1.87	1.65	1.01	**0.83**	**0.84**	**0.88**	—	*0.47*	*0.40*	*0.08*	*0.09*	*0.25*	*0.24*	*0.09*	—
5. Guilt	1.32	1.40	0.89	**0.69**	**0.73**	**0.73**	**0.73**	—	*0.34*	*0.13*	*0.21*	*0.22*	*0.20*	*0.13*	—
6. Betrayal	1.49	1.55	1.07	**0.73**	**0.68**	**0.70**	**0.67**	**0.68**	—	*0.09*	*0.15*	*0.27*	*0.24*	*0.18*	—
7. Hope	1.89	1.60	1.02	**0.33**	**0.38**	**0.29**	**0.30**	**0.43**	**0.37**	—	*0.43*	*0.40*	*0.39*	*0.44*	—
8. Pride	1.34	1.59	1.00	**0.33**	**0.39**	**0.26**	**0.28**	**0.48**	**0.43**	**0.78**	—	*0.45*	*0.43*	*0.55*	—
9. Determination	2.03	1.67	1.04	**0.58**	**0.63**	**0.56**	**0.56**	**0.57**	**0.55**	**0.73**	**0.69**	—	*0.59*	*0.53*	—
10. Compassion	2.01	1.63	1.09	**0.55**	**0.60**	**0.55**	**0.53**	**0.57**	**0.55**	**0.70**	**0.68**	**0.84**	—	*0.49*	—
11. Gratitude	1.71	1.69	1.14	**0.36**	**0.44**	**0.31**	**0.32**	**0.48**	**0.45**	**0.80**	**0.85**	**0.77**	**0.76**	—	—
12. Personal experiences of climate change	2.37	1.62	—	**0.52**	**0.54**	**0.52**	**0.54**	**0.48**	**0.43**	**0.43**	**0.38**	**0.53**	**0.51**	**0.41**	—

Note. Analysis is based on 13,385 observations nested within 3,936 persons. *B* and *W* subscripts indicate between-person (i.e., person-level or "trait") and within-person (i.e., occasion-level or "state") variables, respectively, calculated prior to transformations. Between-person descriptive statistics include a person-level mean (M_b) and a standard deviation of the person-level variable (SD_b). Between-person correlations — that is, the correlations between the average levels of climate emotion for different participants — are located below the diagonal and bolded. Within-person descriptives statistics include an average standard deviation of the occasion-level variable (SD_w). Within-person correlations — that is, the correlations between momentary levels of climate emotions for the same participant — are located above the diagonal and italicized. Climate emotions

were time-varying (collected at Waves 1–5) and personal experiences of climate change were time-invariant (collected at Waves 1 and 3 only and calculated as the average of both measurements).

Dynamic relations among climate emotions estimated by the multivariate multilevel model are shown in Table 3 and illustrated in Figure 2 and Figure 3. Contemporaneous relations are included in Supplementary Table S10 (see Ng et al., 2024). Recognizing the many parameters estimated by the full model, a simplified model was run as a robustness check (see Ng et al., 2024; Supplementary Table S11). On the whole, the pattern of results was consistent across models.

Table 3

Results From Multivariate Multilevel Model Examining Dynamics Among Climate Emotions, Moderated by Personal Experiences of Climate Change

Outcome	Predictor	Estimate	95% CI	*pd*
Anger$_t$				
	Intercept (β_{Ang0})	**−0.05**	**[−0.07, −0.03]**	**100%**
	Anger$_{t-1}$ (β_{Ang1})[a]	**−0.39**	**[−0.41, −0.36]**	**100%**
	Anxiety$_{t-1}$ (β_{Ang2})	**0.04**	**[0.01, 0.06]**	**99.93%**
	Sadness$_{t-1}$ (β_{Ang3})	**0.06**	**[0.03, 0.08]**	**100%**
	Fear$_{t-1}$ (β_{Ang4})	**−0.03**	**[−0.06, 0.00]**	**96.10%**
	Guilt$_{t-1}$ (β_{Ang5})	0.00	[−0.03, 0.03]	54.67%
	Betrayal$_{t-1}$ (β_{Ang6})	−0.01	[−0.04, 0.01]	91.03%
	Hope$_{t-1}$ (β_{Ang7})	0.01	[−0.02, 0.03]	67.53%
	Pride$_{t-1}$ (β_{Ang8})	−0.01	[−0.03, 0.02]	73.60%
	Determination$_{t-1}$ (β_{Ang9})	**0.03**	**[0.00, 0.06]**	**98.93%**
	Compassion$_{t-1}$ (β_{Ang10})	**−0.04**	**[−0.07, −0.02]**	**99.90%**
	Gratitude$_{t-1}$ (β_{Ang11})	0.01	[−0.02, 0.03]	70.10%
	Time$_t$ (β_{Ang12})	**−0.02**	**[−0.04, 0.00]**	**98.23%**
	Experiences (β_{Ang13})	**−0.04**	**[−0.06, −0.02]**	**100%**
	Anger$_{t-1}$ x Experiences (β_{Ang14})	**−0.05**	**[−0.07, −0.02]**	**99.97%**
	Anxiety$_{t-1}$ x Experiences (β_{Ang15})	−0.01	[−0.04, 0.01]	84.67%
	Sadness$_{t-1}$ x Experiences (β_{Ang16})	0.01	[−0.02, 0.04]	79.73%
	Fear$_{t-1}$ x Experiences (β_{Ang17})	0.01	[−0.02, 0.04]	69.50%
	Guilt$_{t-1}$ x Experiences (β_{Ang18})	0.00	[−0.03, 0.03]	54.13%
	Betrayal$_{t-1}$ x Experiences (β_{Ang19})	**0.03**	**[0.01, 0.05]**	**99.77%**
	Hope$_{t-1}$ x Experiences (β_{Ang20})	0.00	[−0.03, 0.02]	65.03%
	Pride$_{t-1}$ x Experiences (β_{Ang21})	−0.01	[−0.04, 0.01]	84.63%
	Determination$_{t-1}$ x Experiences (β_{Ang22})	**−0.02**	**[−0.05, 0.00]**	**96.77%**
	Compassion$_{t-1}$ x Experiences (β_{Ang23})	−0.02	[−0.04, 0.01]	89.13%
	Gratitude$_{t-1}$ x Experiences (β_{Ang24})	**0.04**	**[0.02, 0.06]**	**99.97%**
	Residual, $\sigma_{\varepsilon Ang}$	**0.95**	**[0.94, 0.97]**	**100%**

Outcome	Predictor	Estimate	95% CI	*pd*
Anxiety$_t$				
	Intercept (β_{Anx0})	**−0.04**	**[−0.07, −0.02]**	**100%**
	Anger$_{t-1}$ (β_{Anx1})	0.00	[−0.03, 0.02]	55.40%
	Anxiety$_{t-1}$ (β_{Anx2})[a]	**−0.34**	**[−0.36, −0.31]**	**100%**
	Sadness$_{t-1}$ (β_{Anx3})	−0.01	[−0.04, 0.02]	64.87%
	Fear$_{t-1}$ (β_{Anx4})	0.02	[−0.01, 0.04]	85.63%
	Guilt$_{t-1}$ (β_{Anx5})	−0.02	[−0.05, 0.01]	90.13%
	Betrayal$_{t-1}$ (β_{Anx6})	**0.03**	**[0.00, 0.05]**	**99.40%**
	Hope$_{t-1}$ (β_{Anx7})	0.01	[−0.01, 0.03]	82.80%
	Pride$_{t-1}$ (β_{Anx8})	**−0.03**	**[−0.05, 0.00]**	**98.93%**
	Determination$_{t-1}$ (β_{Anx9})	−0.01	[−0.04, 0.01]	87.87%
	Compassion$_{t-1}$ (β_{Anx10})	−0.02	[−0.04, 0.01]	94.37%
	Gratitude$_{t-1}$ (β_{Anx11})	**0.02**	**[0.00, 0.04]**	**95.17%**
	Time$_t$ (β_{Anx12})	0.01	[−0.01, 0.02]	71.00%
	Experiences (β_{Anx13})	**−0.03**	**[−0.05, −0.01]**	**99.90%**
	Anger$_{t-1}$ x Experiences (β_{Anx14})	**−0.03**	**[−0.06, −0.01]**	**99.43%**
	Anxiety$_{t-1}$ x Experiences (β_{Anx15})	0.00	[−0.02, 0.03]	64.30%
	Sadness$_{t-1}$ x Experiences (β_{Anx16})	0.00	[−0.03, 0.03]	51.40%
	Fear$_{t-1}$ x Experiences (β_{Anx17})	0.01	[−0.02, 0.04]	73.37%
	Guilt$_{t-1}$ x Experiences (β_{Anx18})	0.01	[−0.02, 0.03]	69.17%
	Betrayal$_{t-1}$ x Experiences (β_{Anx19})	0.00	[−0.02, 0.02]	52.93%
	Hope$_{t-1}$ x: Experiences (β_{Anx20})	−0.01	[−0.03, 0.01]	86.03%
	Pride$_{t-1}$ x Experiences (β_{Anx21})	−0.02	[−0.05, 0.00]	94.97%
	Determination$_{t-1}$ x Experiences (β_{Anx22})	0.00	[−0.02, 0.03]	52.00%
	Compassion$_{t-1}$ x Experiences (β_{Anx23})	0.01	[−0.02, 0.03]	69.63%
	Gratitude$_{t-1}$ x Experiences (β_{Anx24})	0.02	[−0.01, 0.04]	91.03%
	Residual, σ_{eAnx}	**0.95**	**[0.94, 0.96]**	**100%**
Sadness$_t$				
	Intercept (β_{Sad0})	**−0.02**	**[−0.04, 0.00]**	**96.60%**
	Anger$_{t-1}$ (β_{Sad1})	−0.01	[−0.03, 0.02]	73.60%
	Anxiety$_{t-1}$ (β_{Sad2})	**0.05**	**[0.02, 0.07]**	**100%**
	Sadness$_{t-1}$ (β_{Sad3})[a]	**−0.34**	**[−0.37, −0.31]**	**100%**
	Fear$_{t-1}$ (β_{Sad4})	0.02	[−0.01, 0.05]	92.07%
	Guilt$_{t-1}$ (β_{Sad5})	−0.02	[−0.05, 0.01]	92.17%
	Betrayal$_{t-1}$ (β_{Sad6})	−0.01	[−0.03, 0.01]	79.03%
	Hope$_{t-1}$ (β_{Sad7})	0.01	[−0.01, 0.03]	80.20%
	Pride$_{t-1}$ (β_{Sad8})	**−0.03**	**[−0.06, −0.01]**	**99.43%**
	Determination$_{t-1}$ (β_{Sad9})	0.02	[−0.01, 0.05]	93.93%
	Compassion$_{t-1}$ (β_{Sad10})	**−0.03**	**[−0.05, −0.01]**	**98.90%**
	Gratitude$_{t-1}$ (β_{Sad11})	0.00	[−0.03, 0.02]	61.53%
	Time$_t$ (β_{Sad12})	0.01	[−0.01, 0.03]	89.53%
	Experiences (β_{Sad13})	**−0.02**	**[−0.04, 0.00]**	**95.53%**
	Anger$_{t-1}$ x Experiences (β_{Sad14})	−0.01	[−0.04, 0.01]	81.83%
	Anxiety$_{t-1}$ x Experiences (β_{Sad15})	0.02	[−0.01, 0.04]	91.53%
	Sadness$_{t-1}$ x Experiences (β_{Sad16})	0.01	[−0.02, 0.04]	78.90%
	Fear$_{t-1}$ x Experiences (β_{Sad17})	−0.02	[−0.04, 0.01]	85.33%
	Guilt$_{t-1}$ x Experiences (β_{Sad18})	−0.02	[−0.05, 0.01]	93.70%
	Betrayal$_{t-1}$ x Experiences (β_{Sad19})	0.01	[−0.01, 0.04]	90.90%
	Hope$_{t-1}$ x Experiences (β_{Sad20})	0.01	[−0.02, 0.03]	71.53%

Outcome	Predictor	Estimate	95% CI	*pd*
	$Pride_{t-1}$ x Experiences (β_{Sad21})	−0.01	[−0.04, 0.01]	81.40%
	$Determination_{t-1}$ x Experiences (β_{Sad22})	**−0.03**	**[−0.05, 0.00]**	**97.30%**
	$Compassion_{t-1}$ x Experiences (β_{Sad23})	0.00	[−0.03, 0.02]	60.70%
	$Gratitude_{t-1}$ x Experiences (β_{Sad24})	0.01	[−0.02, 0.03]	67.77%
	Residual, σ_{eSad}	**0.97**	**[0.96, 0.99]**	**100%**
$Fear_t$				
	Intercept (β_{Fea0})	**−0.05**	**[−0.07, −0.03]**	**100%**
	$Anger_{t-1}$ (β_{Fea1})	0.00	[−0.03, 0.02]	57.73%
	$Anxiety_{t-1}$ (β_{Fea2})	**0.07**	**[0.04, 0.09]**	**100%**
	$Sadness_{t-1}$ (β_{Fea3})	0.02	[−0.01, 0.05]	92.80%
	$Fear_{t-1}$ (β_{Fea4})[a]	**−0.37**	**[−0.4, −0.35]**	**100%**
	$Guilt_{t-1}$ (β_{Fea5})	**−0.03**	**[−0.06, 0.00]**	**97.70%**
	$Betrayal_{t-1}$ (β_{Fea6})	0.00	[−0.03, 0.02]	64.60%
	$Hope_{t-1}$ (β_{Fea7})	0.02	[−0.01, 0.04]	92.57%
	$Pride_{t-1}$ (β_{Fea8})	**−0.03**	**[−0.05, 0.00]**	**98.97%**
	$Determination_{t-1}$ (β_{Fea9})	0.00	[−0.03, 0.02]	54.27%
	$Compassion_{t-1}$ (β_{Fea10})	−0.02	[−0.04, 0.00]	94.90%
	$Gratitude_{t-1}$ (β_{Fea11})	0.00	[−0.02, 0.02]	52.43%
	$Time_t$ (β_{Fea12})	−0.01	[−0.03, 0.01]	81.70%
	Experiences (β_{Fea13})	**−0.03**	**[−0.05, −0.01]**	**99.93%**
	$Anger_{t-1}$ x Experiences (β_{Fea14})	**−0.03**	**[−0.05, 0.00]**	**98.50%**
	$Anxiety_{t-1}$ x Experiences (β_{Fea15})	0.00	[−0.03, 0.02]	58.53%
	$Sadness_{t-1}$ x Experiences (β_{Fea16})	**0.03**	**[0.00, 0.06]**	**98.97%**
	$Fear_{t-1}$ x Experiences (β_{Fea17})	**−0.05**	**[−0.08, −0.02]**	**100%**
	$Guilt_{t-1}$ x Experiences (β_{Fea18})	0.02	[−0.01, 0.04]	87.70%
	$Betrayal_{t-1}$ x Experiences (β_{Fea19})	**0.02**	**[0.00, 0.04]**	**97.47%**
	$Hope_{t-1}$ x Experiences (β_{Fea20})	−0.01	[−0.03, 0.02]	68.47%
	$Pride_{t-1}$ x Experiences (β_{Fea21})	0.00	[−0.02, 0.03]	56.77%
	$Determination_{t-1}$ x Experiences (β_{Fea22})	**−0.03**	**[−0.06, −0.01]**	**99.60%**
	$Compassion_{t-1}$ x Experiences (β_{Fea23})	−0.01	[−0.03, 0.01]	79.77%
	$Gratitude_{t-1}$ x Experiences (β_{Fea24})	0.01	[−0.01, 0.03]	85.37%
	Residual, σ_{eFea}	**0.94**	**[0.93, 0.96]**	**100%**
$Guilt_t$				
	Intercept (β_{Gui0})	**−0.04**	**[−0.06, −0.02]**	**100%**
	$Anger_{t-1}$ (β_{Gui1})	−0.01	[−0.03, 0.01]	87.13%
	$Anxiety_{t-1}$ (β_{Gui2})	**−0.03**	**[−0.05, −0.01]**	**99.80%**
	$Sadness_{t-1}$ (β_{Gui3})	−0.01	[−0.03, 0.02]	68.37%
	$Fear_{t-1}$ (β_{Gui4})	**0.03**	**[0.01, 0.06]**	**99.73%**
	$Guilt_{t-1}$ (β_{Gui5})[a]	**−0.36**	**[−0.39, −0.34]**	**100%**
	$Betrayal_{t-1}$ (β_{Gui6})	0.01	[−0.01, 0.02]	73.87%
	$Hope_{t-1}$ (β_{Gui7})	−0.01	[−0.03, 0.01]	73.70%
	$Pride_{t-1}$ (β_{Gui8})	**−0.03**	**[−0.05, −0.01]**	**99.73%**
	$Determination_{t-1}$ (β_{Gui9})	**0.03**	**[0.01, 0.05]**	**99.73%**
	$Compassion_{t-1}$ (β_{Gui10})	0.00	[−0.02, 0.02]	60.83%
	$Gratitude_{t-1}$ (β_{Gui11})	−0.01	[−0.03, 0.00]	92.57%
	$Time_t$ (β_{Gui12})	**−0.04**	**[−0.06, −0.02]**	**100%**
	Experiences (β_{Gui13})	**−0.03**	**[−0.05, −0.01]**	**100%**
	$Anger_{t-1}$ x Experiences (β_{Gui14})	−0.01	[−0.03, 0.02]	69.43%
	$Anxiety_{t-1}$ x Experiences (β_{Gui15})	**0.06**	**[0.04, 0.08]**	**100%**

Outcome	Predictor	Estimate	95% CI	*pd*
	$Sadness_{t-1}$ x Experiences (β_{Gui16})	0.02	[−0.01, 0.04]	94.40%
	$Fear_{t-1}$ x Experiences (β_{Gui17})	**−0.04**	**[−0.06, −0.01]**	**99.83%**
	$Guilt_{t-1}$ x Experiences (β_{Gui18})	**−0.06**	**[−0.09, −0.04]**	**100%**
	$Betrayal_{t-1}$ x Experiences (β_{Gui19})	**0.03**	**[0.01, 0.05]**	**100%**
	$Hope_{t-1}$ x Experiences (β_{Gui20})	0.01	[−0.01, 0.03]	80.83%
	$Pride_{t-1}$ x Experiences (β_{Gui21})	0.01	[−0.01, 0.04]	90.87%
	$Determination_{t-1}$ x Experiences (β_{Gui22})	**−0.04**	**[−0.06, −0.02]**	**100%**
	$Compassion_{t-1}$ x Experiences (β_{Gui23})	**−0.02**	**[−0.04, 0.00]**	**98.30%**
	$Gratitude_{t-1}$ x Experiences (β_{Gui24})	0.00	[−0.02, 0.02]	60.67%
	Residual, σ_{eGui}	**0.81**	**[0.8, 0.82]**	**100%**
$Betrayal_t$				
	Intercept (β_{Bet0})	**−0.05**	**[−0.07, −0.03]**	**100%**
	$Anger_{t-1}$ (β_{Bet1})	0.01	[−0.01, 0.04]	82.97%
	$Anxiety_{t-1}$ (β_{Bet2})	**0.04**	**[0.02, 0.07]**	**99.97%**
	$Sadness_{t-1}$ (β_{Bet3})	0.01	[−0.02, 0.04]	68.50%
	$Fear_{t-1}$ (β_{Bet4})	−0.01	[−0.05, 0.02]	80.00%
	$Guilt_{t-1}$ (β_{Bet5})	−0.02	[−0.05, 0.01]	92.03%
	$Betrayal_{t-1}$ (β_{Bet6})[a]	**−0.34**	**[−0.36, −0.32]**	**100%**
	$Hope_{t-1}$ (β_{Bet7})	0.00	[−0.03, 0.02]	61.83%
	$Pride_{t-1}$ (β_{Bet8})	−0.02	[−0.05, 0.01]	92.57%
	$Determination_{t-1}$ (β_{Bet9})	**0.03**	**[0.00, 0.05]**	**95.87%**
	$Compassion_{t-1}$ (β_{Bet10})	**−0.03**	**[−0.06, 0.00]**	**98.80%**
	$Gratitude_{t-1}$ (β_{Bet11})	0.00	[−0.02, 0.03]	56.53%
	$Time_t$ (β_{Bet12})	0.02	[0.00, 0.04]	94.87%
	Experiences (β_{Bet13})	**−0.03**	**[−0.05, −0.01]**	**99.67%**
	$Anger_{t-1}$ x Experiences (β_{Bet14})	0.01	[−0.01, 0.04]	83.73%
	$Anxiety_{t-1}$ x Experiences (β_{Bet15})	**0.03**	**[0.01, 0.06]**	**99.23%**
	$Sadness_{t-1}$ x Experiences (β_{Bet16})	0.01	[−0.03, 0.04]	64.70%
	$Fear_{t-1}$ x Experiences (β_{Bet17})	**−0.03**	**[−0.06, 0.00]**	**96.13%**
	$Guilt_{t-1}$ x Experiences (β_{Bet18})	−0.01	[−0.04, 0.02]	80.30%
	$Betrayal_{t-1}$ x Experiences (β_{Bet19})	**−0.03**	**[−0.05, −0.01]**	**99.43%**
	$Hope_{t-1}$ x Experiences (β_{Bet20})	**−0.03**	**[−0.06, −0.01]**	**99.70%**
	$Pride_{t-1}$ x Experiences (β_{Bet21})	−0.01	[−0.04, 0.02]	74.33%
	$Determination_{t-1}$ x Experiences (β_{Bet22})	0.00	[−0.03, 0.02]	62.80%
	$Compassion_{t-1}$ x Experiences (β_{Bet23})	**0.02**	**[0.00, 0.05]**	**95.70%**
	$Gratitude_{t-1}$ x Experiences (β_{Bet24})	**0.03**	**[0.01, 0.05]**	**98.93%**
	Residual, σ_{eBet}	**1.03**	**[1.01, 1.04]**	**100%**
$Hope_t$				
	Intercept (β_{Hop0})	**0.03**	**[0.00, 0.04]**	**99.30%**
	$Anger_{t-1}$ (β_{Hop1})	**−0.03**	**[−0.06, −0.01]**	**99.60%**
	$Anxiety_{t-1}$ (β_{Hop2})	**−0.04**	**[−0.06, −0.01]**	**99.70%**
	$Sadness_{t-1}$ (β_{Hop3})	**0.05**	**[0.02, 0.08]**	**99.90%**
	$Fear_{t-1}$ (β_{Hop4})	−0.01	[−0.04, 0.02]	70.43%
	$Guilt_{t-1}$ (β_{Hop5})	0.01	[−0.02, 0.04]	72.50%
	$Betrayal_{t-1}$ (β_{Hop6})	**0.02**	**[0.00, 0.04]**	**96.30%**
	$Hope_{t-1}$ (β_{Hop7})[a]	**−0.36**	**[−0.38, −0.33]**	**100%**
	$Pride_{t-1}$ (β_{Hop8})	−0.01	[−0.04, 0.01]	81.23%
	$Determination_{t-1}$ (β_{Hop9})	−0.01	[−0.03, 0.02]	70.77%
	$Compassion_{t-1}$ (β_{Hop10})	0.00	[−0.03, 0.02]	58.87%

Outcome	Predictor	Estimate	95% CI	*pd*
	Gratitude$_{t-1}$ (β_{Hop11})	0.01	[−0.01, 0.03]	75.80%
	Time$_t$ (β_{Hop12})	0.01	[−0.01, 0.03]	78.47%
	Experiences (β_{Hop13})	−0.01	[−0.03, 0.01]	91.10%
	Anger$_{t-1}$ x Experiences (β_{Hop14})	0.02	[−0.01, 0.04]	91.87%
	Anxiety$_{t-1}$ x Experiences (β_{Hop15})	**0.05**	**[0.03, 0.08]**	**100%**
	Sadness$_{t-1}$ x Experiences (β_{Hop16})	−0.02	[−0.05, 0.01]	88.70%
	Fear$_{t-1}$ x Experiences (β_{Hop17})	**−0.03**	**[−0.05, 0.00]**	**95.93%**
	Guilt$_{t-1}$ x Experiences (β_{Hop18})	−0.01	[−0.04, 0.02]	79.07%
	Betrayal$_{t-1}$ x Experiences (β_{Hop19})	−0.02	[−0.04, 0.01]	93.23%
	Hope$_{t-1}$ x Experiences (β_{Hop20})	**−0.04**	**[−0.07, −0.02]**	**100%**
	Pride$_{t-1}$ x Experiences (β_{Hop21})	0.00	[−0.03, 0.02]	64.47%
	Determination$_{t-1}$ x Experiences (β_{Hop22})	−0.02	[−0.04, 0.01]	90.90%
	Compassion$_{t-1}$ x Experiences (β_{Hop23})	0.00	[−0.02, 0.03]	63.17%
	Gratitude$_{t-1}$ x Experiences (β_{Hop24})	0.00	[−0.02, 0.02]	50.07%
	Residual, σ_{eHop}	**0.97**	**[0.96, 0.98]**	**100%**
Pride$_t$				
	Intercept (β_{Pri0})	−0.01	[−0.03, 0.01]	77.33%
	Anger$_{t-1}$ (β_{Pri1})	**−0.05**	**[−0.08, −0.03]**	**100%**
	Anxiety$_{t-1}$ (β_{Pri2})	**−0.05**	**[−0.07, −0.02]**	**99.93%**
	Sadness$_{t-1}$ (β_{Pri3})	**0.05**	**[0.02, 0.07]**	**99.87%**
	Fear$_{t-1}$ (β_{Pri4})	−0.02	[−0.05, 0.01]	92.43%
	Guilt$_{t-1}$ (β_{Pri5})	**0.06**	**[0.03, 0.08]**	**100%**
	Betrayal$_{t-1}$ (β_{Pri6})	**0.04**	**[0.02, 0.06]**	**100%**
	Hope$_{t-1}$ (β_{Pri7})	**0.02**	**[0.00, 0.05]**	**97.73%**
	Pride$_{t-1}$ (β_{Pri8})[a]	**−0.39**	**[−0.41, −0.36]**	**100%**
	Determination$_{t-1}$ (β_{Pri9})	**−0.03**	**[−0.06, −0.01]**	**99.50%**
	Compassion$_{t-1}$ (β_{Pri10})	0.00	[−0.03, 0.02]	57.57%
	Gratitude$_{t-1}$ (β_{Pri11})	**0.03**	**[0.01, 0.06]**	**99.90%**
	Time$_t$ (β_{Pri12})	0.01	[−0.01, 0.03]	76.67%
	Experiences (β_{Pri13})	**−0.02**	**[−0.04, 0.00]**	**96.63%**
	Anger$_{t-1}$ x Experiences (β_{Pri14})	0.01	[−0.02, 0.03]	67.77%
	Anxiety$_{t-1}$ x Experiences (β_{Pri15})	**0.07**	**[0.04, 0.09]**	**100%**
	Sadness$_{t-1}$ x Experiences (β_{Pri16})	0.01	[−0.02, 0.04]	73.53%
	Fear$_{t-1}$ x Experiences (β_{Pri17})	**−0.06**	**[−0.09, −0.03]**	**100%**
	Guilt$_{t-1}$ x Experiences (β_{Pri18})	−0.02	[−0.05, 0.01]	90.03%
	Betrayal$_{t-1}$ x Experiences (β_{Pri19})	0.01	[−0.01, 0.03]	85.50%
	Hope$_{t-1}$ x Experiences (β_{Pri20})	−0.01	[−0.03, 0.01]	76.07%
	Pride$_{t-1}$ x Experiences (β_{Pri21})	−0.02	[−0.05, 0.00]	94.67%
	Determination$_{t-1}$ x Experiences (β_{Pri22})	−0.01	[−0.04, 0.01]	79.43%
	Compassion$_{t-1}$ x Experiences (β_{Pri23})	0.00	[−0.02, 0.03]	51.93%
	Gratitude$_{t-1}$ x Experiences (β_{Pri24})	**−0.02**	**[−0.04, 0.00]**	**95.63%**
	Residual, σ_{ePri}	**0.96**	**[0.95, 0.98]**	**100%**
Determination$_t$				
	Intercept (β_{Det0})	0.00	[−0.02, 0.02]	50.50%
	Anger$_{t-1}$ (β_{Det1})	**−0.03**	**[−0.06, −0.01]**	**99.57%**
	Anxiety$_{t-1}$ (β_{Det2})	−0.02	[−0.04, 0.01]	88.07%
	Sadness$_{t-1}$ (β_{Det3})	0.02	[−0.01, 0.05]	88.67%
	Fear$_{t-1}$ (β_{Det4})	**0.03**	**[0.00, 0.06]**	**98.37%**
	Guilt$_{t-1}$ (β_{Det5})	−0.02	[−0.05, 0.01]	88.37%

Outcome	Predictor	Estimate	95% CI	*pd*
	Betrayal$_{t-1}$ (β_{Det6})	0.01	[−0.01, 0.03]	81.77%
	Hope$_{t-1}$ (β_{Det7})	**0.04**	**[0.02, 0.07]**	**99.97%**
	Pride$_{t-1}$ (β_{Det8})	**−0.04**	**[−0.07, −0.01]**	**99.93%**
	Determination$_{t-1}$ (β_{Det9})[a]	**−0.35**	**[−0.38, −0.33]**	**100%**
	Compassion$_{t-1}$ (β_{Det10})	0.02	[−0.01, 0.04]	89.60%
	Gratitude$_{t-1}$ (β_{Det11})	0.01	[−0.02, 0.03]	74.33%
	Time$_t$ (β_{Det12})	0.00	[−0.02, 0.02]	51.53%
	Experiences (β_{Det13})	−0.01	[−0.04, 0.01]	91.87%
	Anger$_{t-1}$ x Experiences (β_{Det14})	**0.04**	**[0.01, 0.06]**	**99.97%**
	Anxiety$_{t-1}$ x Experiences (β_{Det15})	**0.03**	**[0.01, 0.06]**	**99.63%**
	Sadness$_{t-1}$ x Experiences (β_{Det16})	0.01	[−0.02, 0.03]	65.70%
	Fear$_{t-1}$ x Experiences (β_{Det17})	**−0.04**	**[−0.07, −0.01]**	**99.80%**
	Guilt$_{t-1}$ x Experiences (β_{Det18})	−0.01	[−0.04, 0.02]	71.00%
	Betrayal$_{t-1}$ x Experiences (β_{Det19})	−0.01	[−0.03, 0.02]	72.27%
	Hope$_{t-1}$ x Experiences (β_{Det20})	−0.01	[−0.03, 0.02]	66.00%
	Pride$_{t-1}$ x Experiences (β_{Det21})	0.00	[−0.02, 0.03]	56.50%
	Determination$_{t-1}$ x Experiences (β_{Det22})	**−0.04**	**[−0.07, −0.01]**	**99.70%**
	Compassion$_{t-1}$ x Experiences (β_{Det23})	0.01	[−0.02, 0.04]	74.13%
	Gratitude$_{t-1}$ x Experiences (β_{Det24})	0.00	[−0.02, 0.02]	50.77%
	Residual, σ_{eDet}	**0.99**	**[0.98, 1.01]**	**100%**
Compassion$_t$				
	Intercept (β_{Com0})	0.00	[−0.02, 0.02]	55.97%
	Anger$_{t-1}$ (β_{Com1})	**−0.03**	**[−0.06, 0.00]**	**98.10%**
	Anxiety$_{t-1}$ (β_{Com2})	0.00	[−0.03, 0.02]	64.23%
	Sadness$_{t-1}$ (β_{Com3})	**0.05**	**[0.02, 0.08]**	**99.80%**
	Fear$_{t-1}$ (β_{Com4})	0.02	[−0.01, 0.06]	94.10%
	Guilt$_{t-1}$ (β_{Com5})	−0.02	[−0.05, 0.01]	87.23%
	Betrayal$_{t-1}$ (β_{Com6})	**0.03**	**[0.01, 0.05]**	**99.30%**
	Hope$_{t-1}$ (β_{Com7})	**0.04**	**[0.02, 0.07]**	**100%**
	Pride$_{t-1}$ (β_{Com8})	0.00	[−0.02, 0.03]	62.07%
	Determination$_{t-1}$ (β_{Com9})	−0.01	[−0.04, 0.02]	80.43%
	Compassion$_{t-1}$ (β_{Com10})[a]	**−0.40**	**[−0.42, −0.37]**	**100%**
	Gratitude$_{t-1}$ (β_{Com11})	0.01	[−0.02, 0.03]	71.23%
	Time$_t$ (β_{Com12})	0.01	[−0.01, 0.03]	79.23%
	Experiences (β_{Com13})	**−0.02**	**[−0.04, 0.00]**	**95.73%**
	Anger$_{t-1}$ x Experiences (β_{Com14})	0.01	[−0.02, 0.03]	67.33%
	Anxiety$_{t-1}$ x Experiences (β_{Com15})	0.01	[−0.02, 0.03]	67.17%
	Sadness$_{t-1}$ x Experiences (β_{Com16})	0.00	[−0.03, 0.04]	59.87%
	Fear$_{t-1}$ x Experiences (β_{Com17})	−0.02	[−0.05, 0.01]	92.07%
	Guilt$_{t-1}$ x Experiences (β_{Com18})	0.01	[−0.02, 0.04]	79.87%
	Betrayal$_{t-1}$ x Experiences (β_{Com19})	−0.01	[−0.04, 0.01]	87.50%
	Hope$_{t-1}$ x Experiences (β_{Com20})	−0.01	[−0.03, 0.01]	77.90%
	Pride$_{t-1}$ x Experiences (β_{Com21})	0.00	[−0.02, 0.03]	57.00%
	Determination$_{t-1}$ x Experiences (β_{Com22})	**−0.03**	**[−0.06, 0.00]**	**98.93%**
	Compassion$_{t-1}$ x Experiences (β_{Com23})	0.00	[−0.03, 0.02]	57.60%
	Gratitude$_{t-1}$ x Experiences (β_{Com24})	0.02	[−0.01, 0.04]	93.03%
	Residual, σ_{eCom}	**1.02**	**[1.01, 1.03]**	**100%**

Outcome	Predictor	Estimate	95% CI	*pd*
Gratitude$_t$				
	Intercept (β_{Gra0})	**0.02**	**[0.00, 0.04]**	**95.60%**
	Anger$_{t-1}$ (β_{Gra1})	**−0.05**	**[−0.08, −0.03]**	**99.97%**
	Anxiety$_{t-1}$ (β_{Gra2})	**−0.03**	**[−0.06, 0.00]**	**97.03%**
	Sadness$_{t-1}$ (β_{Gra3})	**0.03**	**[0.00, 0.06]**	**97.53%**
	Fear$_{t-1}$ (β_{Gra4})	0.00	[−0.03, 0.04]	57.60%
	Guilt$_{t-1}$ (β_{Gra5})	**−0.03**	**[−0.06, 0.00]**	**95.87%**
	Betrayal$_{t-1}$ (β_{Gra6})	**0.03**	**[0.00, 0.05]**	**97.90%**
	Hope$_{t-1}$ (β_{Gra7})	0.01	[−0.02, 0.03]	66.90%
	Pride$_{t-1}$ (β_{Gra8})	0.00	[−0.03, 0.03]	51.47%
	Determination$_{t-1}$ (β_{Gra9})	−0.01	[−0.04, 0.02]	68.73%
	Compassion$_{t-1}$ (β_{Gra10})	0.01	[−0.02, 0.04]	77.67%
	Gratitude$_{t-1}$ (β_{Gra11})[a]	**−0.36**	**[−0.38, −0.33]**	**100%**
	Time$_t$ (β_{Gra12})	0.00	[−0.02, 0.02]	55.10%
	Experiences (β_{Gra13})	−0.01	[−0.03, 0.01]	81.83%
	Anger$_{t-1}$ x Experiences (β_{Gra14})	0.01	[−0.02, 0.03]	71.23%
	Anxiety$_{t-1}$ x Experiences (β_{Gra15})	**0.06**	**[0.03, 0.08]**	**100%**
	Sadness$_{t-1}$ x Experiences (β_{Gra16})	0.00	[−0.04, 0.03]	55.97%
	Fear$_{t-1}$ x Experiences (β_{Gra17})	**−0.05**	**[−0.08, −0.01]**	**99.83%**
	Guilt$_{t-1}$ x Experiences (β_{Gra18})	−0.02	[−0.05, 0.02]	84.33%
	Betrayal$_{t-1}$ x Experiences (β_{Gra19})	0.01	[−0.02, 0.03]	70.90%
	Hope$_{t-1}$ x Experiences (β_{Gra20})	−0.01	[−0.03, 0.02]	74.97%
	Pride$_{t-1}$ x Experiences (β_{Gra21})	0.02	[−0.01, 0.05]	89.47%
	Determination$_{t-1}$ x Experiences (β_{Gra22})	−0.01	[−0.04, 0.02]	79.97%
	Compassion$_{t-1}$ x Experiences (β_{Gra23})	−0.02	[−0.05, 0.01]	91.13%
	Gratitude$_{t-1}$ x Experiences (β_{Gra24})	−0.02	[−0.04, 0.01]	88.93%
	Residual, $\sigma_{\varepsilon Gra}$	**1.09**	**[1.07, 1.10]**	**100%**

Note. Analysis based on n = 13,385 observations nested within N = 3,936 participants. Bolded numbers indicate a pd > 95%.

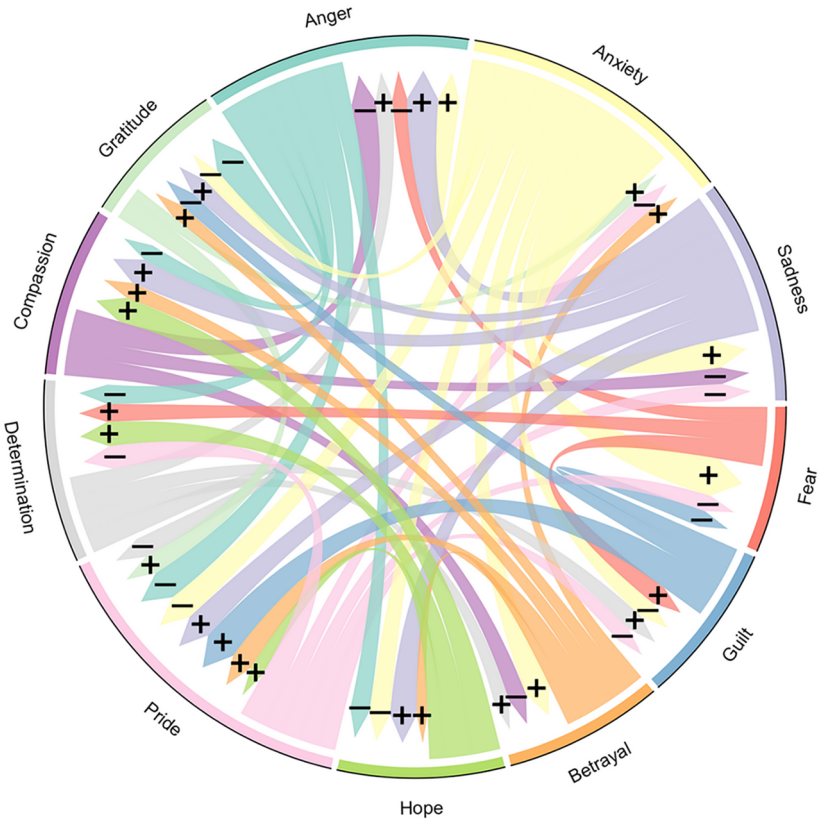
[a] Negative autoregressive dynamic relations are naturally implied by our use of state variables in the model. Since state variables were calculated as an individual's deviation from their own mean, higher levels of state variables at one time point are followed by lower levels of state variables at the next point since they must average out to the mean across the five occasions.

Temporal Dynamics Among Climate Emotions

To address RQ1, we examined the temporal dynamics among 11 climate emotions (β_{Emo1} to β_{Emo11}). Negative autoregressive dynamic relations (accompanying our modelling of within-person variables) were consistent across all 11 climate emotions. In other words, following more extreme levels of any climate emotion at one wave, participants tended to experience less extreme levels of that same emotion at the next wave. Since a ceiling effect was not observed in the data, these inhibitory dynamics suggest that individuals self-regulate their climate emotions.

Figure 2

Within-Person Dynamics Among Climate Emotions

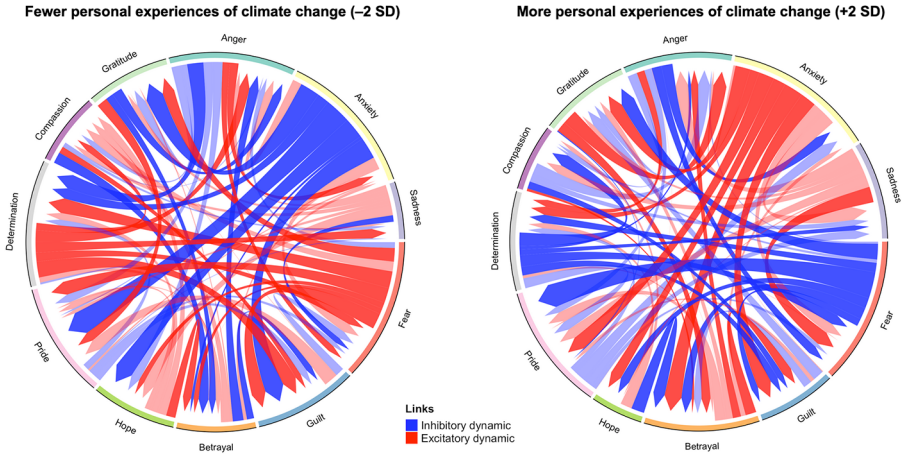


Note. Chord diagram of the cross-lagged dynamic relations among 11 climate emotions that exceeded a threshold of *pd* > 95%. Arrow tails (flat) denote predictor variables at $time_{t-1}$, arrow heads (pointed) denoting outcome variables at $time_t$, and the width of the arrows indicating the absolute value of the strength of association. "+" signs indicate a positive dynamic relation (excitatory) and "−" signs indicate a negative dynamic relation (inhibitory). For parsimony of presentation, negative autoregressive dynamic relations are not shown.

More interesting are 40 cross-lagged dynamic relations among climate emotions shown in Figure 2. For example, climate fear exhibited some inhibitory dynamics, such as higher levels of fear at one wave associating with lower levels of hope at the next wave (β_{Hop4} = −0.01), and some excitatory dynamics, such as higher levels of fear at one wave associating with higher levels of determination at the next wave (β_{Det4} = 0.03).

Figure 3

Within-Person Dynamics Among Climate Emotions for Participants With Different Levels of Personal Experiences of Climate Change



Note. Chord diagrams showing cross-lagged dynamic relations (inhibitory = blue; excitatory = red) among climate emotions that exceeded a threshold of $pd > 95\%$ (lower opacity) and dynamic relations moderated by personal experiences of climate change that exceeded a threshold of $pd > 95\%$ (higher opacity) for model-implied participants with 2 standard deviations fewer personal experiences of climate change than average (left panel) and 2 standard deviations more personal experiences of climate change than average (right panel). Arrow tails (flat) denote predictor variables at $time_{t-1}$, arrow heads (pointed) denote outcome variables at $time_t$, and the width of the arrows indicating the absolute value of the strength of association. For parsimony of presentation, autoregressive dynamic relations are not shown. *SD* = standard deviation.

The heterogeneity in climate emotion dynamics suggests differences in both their sensitivity to other emotions and their centrality within the network. Climate pride was most sensitive to prior levels of other climate emotions, receiving inhibitory and excitatory input from anger, anxiety, sadness, guilt, betrayal, hope, determination, and gratitude ($\beta_{Pri1} = -0.05$, $\beta_{Pri2} = -0.05$, $\beta_{Pri3} = 0.05$, $\beta_{Pri5} = 0.06$, $\beta_{Pri6} = 0.04$, $\beta_{Pri7} = 0.02$, $\beta_{Pri9} = -0.03$, $\beta_{Pri11} = 0.03$). Climate fear, anxiety, and sadness were the least sensitive — with climate fear, for instance, only receiving excitatory input from anxiety ($\beta_{Fea2} = 0.07$) and inhibitory input from guilt and pride ($\beta_{Fea5} = -0.03$, $\beta_{Fea8} = -0.03$). Climate anxiety was most central in the network, providing excitatory input to anger, sadness, fear, and betrayal ($\beta_{Ang2} = 0.06$, $\beta_{Sad2} = 0.05$, $\beta_{Fea2} = 0.07$, $\beta_{Bet2} = 0.04$) and inhibitory input to guilt, hope, pride, and gratitude ($\beta_{Gui2} = -0.03$, $\beta_{Hop2} = -0.04$, $\beta_{Pri2} = -0.05$, $\beta_{Gra2} = -0.03$); while climate gratitude was least central, only providing excitatory input to anxiety and pride ($\beta_{Anx11} = 0.02$, $\beta_{Pri11} = 0.03$). Overall, the dynamic network analysis portrays a complex climate emotional system featuring inhibitory and excitatory dynamics between different pairs of climate emotions.

Personal Experiences of Climate Change as a Moderator of Climate Emotions Dynamics

To address RQ2, we examined how dynamics among 11 climate emotions were moderated by personal experiences of climate change (β_{Emo14} to β_{Emo24}). As shown in Table 2, personal experiences of climate change moderated 51 (of 110) dynamic relations between pairs of climate emotions. In some places in the network, having more personal experiences of climate change strengthened excitatory dynamics (e.g., high levels of climate anxiety at one wave predicted even higher levels of betrayal at the next wave, β_{Bet15} = 0.03). In other places in the network, having more personal experiences of climate change strengthened inhibitory dynamics (e.g., high levels of climate anxiety at one wave predicted even lower levels of gratitude at the next wave, β_{Gra15} = 0.06). Still elsewhere in the network, having more personal experiences of climate change attenuated excitatory dynamics (e.g., high levels of climate determination at one wave predicted levels of guilt closer to equilibrium at the next wave, β_{Gui22} = −0.04). Nowhere in the network did having more personal experiences of climate change attenuate inhibitory dynamics between climate emotions.

The model-implied climate emotion dynamics for participants with fewer (left panel) and more (right panel) personal experiences of climate change are shown in Figure 3. The networks of participants with fewer personal experiences of climate change were generally characterized by more dynamic relations (36) — indicating more interdependence — than those with more personal experiences (26). Color differences across the panels show that some climate emotions shifted between inhibitory (blue) and excitatory (red) relations depending on personal experiences of climate change. For instance, anxiety was consistently inhibitory for participants with fewer personal experiences of climate change but consistently excitatory for participants with more. In contrast, fear and determination were consistently inhibitory for participants with fewer personal experiences of climate change but consistently excitatory for participants with more. Taken together, these results suggest that individuals' personal experiences of climate change shape the interdependence of their climate emotion networks.

Discussion

Applying a multivariate multilevel model to five-wave panel data obtained from a large representative sample of American adults, this study examined the temporal dynamics among climate emotions and how they vary with personal experiences of climate change. This dynamic network approach accommodates the known complexity of individuals' climate emotions articulated in Pihkala's (2022b) taxonomy of climate emotions and demonstrated by empirical studies. We found that climate emotions change interdependently in a network featuring both inhibitory and excitatory dynamics. Personal experi-

ences of climate change moderate the dynamics among climate emotions, suggesting these dynamics may evolve as individuals are exposed to the impacts of climate change. In general, individuals with fewer personal experiences of climate change appear to exhibit more dynamics — that is, more interdependence — among climate emotions than individuals with more personal experiences.

Theoretical and Practical Implications

For RQ1, we found evidence of temporal dynamics among climate emotions that manifest differently across pairs of climate emotions. For instance, we observed an excitatory dynamic between climate anxiety and fear and an inhibitory dynamic between climate anxiety and hope. In contrast, Contreras and colleagues (2024) found consistently excitatory dynamics among climate emotions. The discrepancy could be due to the slower timescale at which we examined dynamics (seven-week intervals versus daily intervals), the broader range of climate emotions examined (11 positive and negative emotions versus three negative emotions), or the different populations studied (American adults versus Belgian adults). Additionally, our results suggest that dynamics among climate emotions differ from those among general emotions. While general emotions with the same valence tend to excite one another and general emotions with opposite valences tend to inhibit one another (Pe & Kuppens, 2012), climate emotions appear to excite and inhibit other climate emotions across the positive–negative valence dimension. One possible explanation for negative emotions relating to higher subsequent levels of positive emotions (e.g., climate fear and determination) is shifting appraisals of climate change (Siemer et al., 2007). Alternatively, that same dynamic could be explained by emotional goal pursuit, whereby individuals strive to avoid negative emotions and experience positive emotions (Ford, 2025). Although effect sizes were generally small, our ability to detect temporal dynamics at all within longitudinal data collected from individuals as they went about their everyday lives over eight months — data that tend to include substantial noise — warrants further investigation of how and why such dynamics may be manifesting in individuals' lives.

Furthermore, we observed that climate emotions vary in their number of dynamic relations with other climate emotions — that is, in their sensitivity and centrality. Sensitivity refers to the extent to which certain climate emotions relate to the prior levels of other climate emotions. On the upper extreme of sensitivity, climate pride is sensitive to the prior levels of eight climate emotions, possibly because it is a social emotion (Jacquet, 2017; Shipley & van Riper, 2022). As a social emotion, climate pride may be informed by a wider range of climate-related appraisals (including, for instance, social factors like personal responsibility and trust in institutions), making it more sensitive than other emotions with narrower appraisal scopes. On the lower extreme of sensitivity, climate anxiety, sadness, and fear are each sensitive to the prior levels of only three climate emotions. Lack of sensitivity does not imply these emotions are static; rather, it suggests

they are driven by factors outside the climate emotion network (e.g., self-efficacy, climate vulnerability, mental health). We speculate that these three climate emotions are shaped more directly by climate change itself than by changes in other climate emotions, with climate anxiety arising from the uncertainties climate change creates (Clayton, 2020; Ojala et al., 2021), climate sadness from the losses it causes (Cunsolo et al., 2020), and climate fear from the direct, immediate threats it poses (Clayton, 2020; Ojala et al., 2021).

Centrality refers to the extent to which certain climate emotions relate to the subsequent levels of other climate emotions. On the upper extreme of centrality, climate anxiety is central to the subsequent levels of eight climate emotions. As a future-oriented emotion that appraises unclear threats (Clayton, 2020; Ojala et al., 2021), it is possible that climate anxiety underpins other future-oriented emotions (e.g., hope), informs interpretations of current losses and threats (e.g., sadness, fear), and shapes one's judgments of oneself (e.g., guilt, pride) and others (e.g., anger, betrayal, gratitude). Borrowing the ecological concept of "keystone" species, which play an outsized role in their ecosystems (Mills et al., 1993), climate anxiety may serve as a "keystone" emotion that plays an outsized role in individuals' climate emotion networks — suggesting its potential utility as a target for interventions. On the lower extreme of centrality, climate gratitude provides input to the subsequent levels of only two climate emotions: anxiety and pride. With climate gratitude often emerging from collective action (Marczak et al., 2023), it may increase subsequent anxiety when one's personal concerns are validated by the actions of others and increase subsequent pride when one feels they have performed socially desirable behaviors (Shipley & van Riper, 2022). Overall, our findings show that climate emotions exhibit inhibitory and excitatory dynamics and are characterized by varying levels of sensitivity to other emotions and centrality within individuals' climate emotion networks.

Notably, dynamics among climate emotions follow different patterns than those proposed by taxonomies of eco-emotions and climate emotions. For example, the dynamics we observed in these data do not systematically align with distinctions in valence (Pihkala, 2022b), "self" and "other" appraisal targets (Landmann, 2020), or "understanding" and "action" functions (Georgiou & Van Lange, 2026) — distinctions that were developed based on cross-sectional studies. While cross-sectional relations (e.g., Hickman et al., 2021) and our between-person correlations (Table 2) suggest that a person who experiences one negative climate emotion is likely to experience other negative emotions, our within-person analysis shows that climate sadness at one time point does not systematically relate to other negative emotions, like anxiety or fear, at the next time point (though it does relate to some positive emotions, like hope and compassion). In other words, negative climate emotions may co-occur at one time point, but experiencing one negative emotion does not reliably give rise to others over time. As a result, care should be taken not to assume that cross-sectional relations among climate emotions persist longitudinally. If climate action and well-being are indeed driven by climate emotions

(e.g., Stanley et al., 2021; van Valkengoed & Steg, 2019), then a better understanding of temporal dynamics among climate emotions is critical for motivating climate action and promoting well-being over time.

For RQ2, we found that personal experiences of climate change moderate the number and types of dynamics among climate emotions. Regarding number of dynamics, individuals with fewer personal experiences of climate change appear to exhibit more dynamics — that is, more interdependence — among climate emotions than those with more personal experiences. Regarding types of dynamics, different personal experiences of climate change appear to strengthen certain excitatory dynamics (e.g., climate anxiety and betrayal) and inhibitory dynamics (e.g., climate anxiety and gratitude), while attenuating other excitatory dynamics (e.g., climate determination and guilt). For example, higher levels of climate anxiety were related to *lower* subsequent levels of hope, pride, determination, and gratitude for individuals with fewer personal experiences of climate change, but with *higher* subsequent levels of those same emotions for individuals with more personal experiences. Speculatively, it is possible that people with different personal experiences of climate change are at different stages in their ecological grief process (Pihkala, 2022a), perceive less psychological distance of climate change (McDonald et al., 2015; Trope & Liberman, 2010), or appraise climate change differently. For instance, someone with fewer personal experiences of climate change may appraise it as an ambiguous, abstract threat, while someone with more personal experiences of climate change may appraise it as a familiar threat they know how to manage. Overall, our results demonstrate that individuals' personal experiences of climate change relate to not only their climate emotions at a given time (Demski et al., 2017; Demuth et al., 2016; Lewandowski et al., 2024), but also how their entire climate emotion network changes over time.

In addition to building on the taxonomy of climate emotions, our results open new possibilities for climate adaptation practice. First, a better understanding of climate emotion dynamics enhances our ability to motivate climate action. Emotions — especially fear — have long been considered an important pathway by which risk communication motivates action (Chapman et al., 2017; Roeser, 2012; Witte, 1992). Our results highlight an additional "keystone" emotion that could be relevant for climate risk communication: anxiety. Although climate anxiety is central to the experiences of eight other climate emotions, further research is necessary to ascertain whether it also relates to climate action. Second, a better understanding of climate emotion dynamics enhances our ability to promote well-being. Such knowledge could support climate-aware therapists in guiding their patients through the process of ecological grief or educators in supporting their students through lessons about climate change (Hill-Harding et al., in press; Quitmann et al., 2023). Altogether, knowledge of climate emotion dynamics could help promote climate action and well-being via climate risk communication and climate-aware therapy and pedagogies.

Limitations and Future Work

It is important to acknowledge several limitations of our study. First, although we used survey weights, the sample was comprised of more politically affiliated (i.e., those who identify with a political party), older, White, and male individuals than the national population and thus may not generalize to all Americans. For instance, climate emotions — like general emotions — may be culture-specific (Jackson et al., 2019); and those living in climate frontline communities may have additionally strengthened or attenuated dynamics among their climate emotions than those detected here. Second, participants' personal experiences of climate change over their lifetime were measured using a single time-invariant item that aggregated across climate impacts. As a result, we do not know the specific climate hazards they experienced, their severity, when they occurred, and whether any were experienced during the eight-month study duration. Nuances in how participants' multifaceted experiences of climate change moderate their climate emotion dynamics may have been missed. Third, our longitudinal data were comprised of five surveys completed at seven-week intervals. If climate emotions change at the same rapid timescale as general emotions, they may have fluctuated more quickly than captured here. In addition, participants' climate emotion appraisals may have been partially driven by factors beyond climate change, such as the 2024 presidential election, engagement with climate change news, or participation in collective climate action (Cologna et al., 2021; Feldman & Hart, 2018). Even if participants' climate emotions were solely driven by their appraisals of climate change, they may have appraised different aspects of the complex phenomenon, from threatened ecosystems to societal response to consequences for future generations (e.g., Geiger et al., 2023; Gregersen et al., 2023). Fourth, applying a multivariate multilevel model to five-wave panel data invoked a homogeneity assumption: that all individuals exhibit the same climate emotion dynamics. While we allowed for person-specific random effects in the intercepts of each climate emotion, five-wave data did not support modeling of person-specific random effects in their dynamic relations. Consequently, our model resembles a variety of approaches used to examine multivariate change in psychology, including random-intercept cross-lagged panel models, longitudinal actor-partner interdependence models, and Bayesian networks. In contrast to typical implementations of these models, we also controlled for linear time effects to reduce the risk that observed interdependencies were driven by a common-fate change process. Future work could expand the model to explore more nuanced individual differences in climate emotion dynamics.

Building on this exploratory study, future studies that obtain more frequent and more precise measurements of individuals' climate emotions (including and beyond those examined here) and personal experiences of climate change will be able to parse within-person climate emotion dynamics even more thoroughly. For example, those data could reveal whether the subtle effects found here also manifest in different populations, at different timescales, and with other combinations of climate emotions. Future work

could also investigate the antecedents of change in climate emotions — such as engaging with climate change news (Feldman & Hart, 2018), participating in collective climate action (Cologna et al., 2021), and shifting appraisals of climate change (Siemer et al., 2007) — and the consequences of change in climate emotions, such as climate action and well-being. Finally, future work could build on our results to examine additional group-based differences in within-person dynamics among climate emotions.

Conclusion

Applying a dynamic network analysis to five-wave panel data, we found evidence for temporal dynamics among 11 climate emotions. Beyond co-occurring at one time point and changing over time, individuals' climate emotions change interdependently over time, with levels of climate emotions at one time point (especially climate anxiety) relating to levels of other climate emotions at subsequent time points in both excitatory and inhibitory patterns. Moreover, individuals' climate emotion dynamics appear to be moderated by their personal experiences of climate change, suggesting that climate emotion networks evolve as people are exposed to the impacts of climate change. Theoretically, our results characterize the prevalence and types of dynamics among climate emotions and demonstrate how individuals' lived experiences shape those dynamics. Practically, our results may inform practical interventions, such as climate risk communication and climate-aware therapy and pedagogies, that better promote climate action and well-being.

Openness and Transparency Statements

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Author Contributions.

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Ethics Statement. This research was approved by the Research Ethics Board at Indiana University (Protocol #23159).

Diversity Statement. In the list below, the check mark (☑) indicates which steps were taken to increase diversity within the context of this paper. Steps that were not taken or did not apply are unmarked (☐).

- ☑ Ethnically or otherwise diverse sample(s)
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- ☑ Sampling justification
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- ☐ Degree of privilege/marginalization considered in authorship order
- ☑ Author(s) from sampled population (avoiding 'helicopter science')

Data Availability. All supplementary materials, data, codebook, and code are openly available through the OSF at Ng et al. (2024).

Supplementary Materials. The following table provides an overview of the accessibility of supplementary materials (if any) for this paper.

Type of supplementary material	Availability/Access
Data	
Climate Emotions Data	Ng et al. (2024)
Code	
Climate Emotions Code	Ng et al. (2024)
Material	
Climate Emotion Dynamics Supplementary Materials Final - Compliance Table: S1	Ng et al. (2024)
Climate Emotion Dynamics Supplementary Materials Final - Attrition Analyses Tables: S2–S9	Ng et al. (2024)
Climate Emotion Dynamics Supplementary Materials Final - Contemporaneous Relations Among Climate Emotions Table: S10	Ng et al. (2024)
Climate Emotion Dynamics Supplementary Materials Final - Robustness Check Table: S11	Ng et al. (2024)
Study/Analysis preregistration	
PAP - Examining Climate Emotions That Accompany Personal Experiences of Climate Change - A Multivariate Dynamic Network Analysis	Ng et al. (2024)
Other	
Climate Emotions Codebook	Ng et al. (2024)

Badges for Good Research Practices.

Open data: YES.

Open code: YES.

Open materials: YES.

Preregistration: YES.

Diversity statement: YES.

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