BAMS
In Box

Public Engagement on Weather and Climate with a Monsoon Fantasy Forecasting Game

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ABSTRACT: The North American monsoon generates heavy rainfall across the southwestern United States between July and September, delivering beneficial moisture to the region and creating hazards that affect public and personal safety. The monsoon thus has the rapt attention of the public and science community, providing an opportunity to improve weather and climate literacy and public engagement in science. Engaging the public to forecast weather and climate phenomenon through contests offers an innovative way to reach diverse audiences and increase weather and climate literacy. We describe a "Monsoon Fantasy Forecasting" game conducted in 2021 with approximately 300 participants. The game that engaged the public in the forecasting of monthly rainfall at cities in Arizona, New Mexico, and Texas. We report on the game's interactive design, results, and feedback. We show that the game attracted a diverse audience who was not the typical weather and climate enthusiast, and we provide suggestive results that the game may have influenced the players information-seeking behaviors. We argue that activities that provoke people to observe and think routinely about climate can help educate and build awareness about weather and climate issues.

KEYWORDS: Monsoons; Seasonal forecasting; Climate services; Decision support; Resilience

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Climate and weather hazards cause losses in life and property each year. In the United States alone, economic development in combination with population growth and extreme weather have led to more than 258 billion-dollar disasters since 1980 (Smith 2020). Governments and the private sector have invested large amounts in infrastructure and technical capacity to monitor and predict the weather and climate (Georgeson et al. 2017) with profound benefits to society (Alley et al. 2019). However, vulnerability to weather and climate is on the rise (IPCC 2022), and advancing risk communication, awareness, and education are important steps to build resilience. Not surprisingly, scientists have called for new ways to engage with the public (Dilling and Lemos 2011; Hall and Endfield 2016; Lejano et al. 2013; Wu and Lee 2015).

Games have been a long-used platform to educate, build awareness, and motivate actions (Kwok 2019). Games not only circumvent a pitfall of science education, which reduces the public to passive listeners (Lejano et al. 2013), but are a counterweight to the information deficit theory of risk communication, which assumes that providing more and better information should lead to positive change (Rooney-Varga et al. 2018). Games allow people to learn for themselves through experience and experimentation (Pearce et al. 2015; Sterman 2011).

In this article, we report on a "Monsoon Fantasy Forecasting" game played in 2021 during the monsoon months of July–September. During this period, public interest in weather and climate in the Southwest peaks.[1] In fact, "Will it be a wet monsoon?" is an ever-present question in months prior to, and throughout, the season. Indeed, weather forecasting during the monsoon, even at hourly and daily lead times, is difficult (Risanto et al. 2019). Rather than responding to the question with a shrug, the game asks the players to make their own forecasts.

The game drew its motivation from research that suggests that when knowledge exists only in a technical form—such as rainfall statistics—it is separate from how people understand the world and, in turn, how they act (Lejano et al. 2013). The experience of daily weather creates meaningful experiences that develop an individual's understanding of the climate (Hall and Endfield 2016). Over time, these experience creates a sense of identity and place, both individually and collectively (Veale et al. 2014; Casey 1996). As an additional benefit, games can elicit positive emotions that expand the desire to learn and act (Fredrickson 2013). It is from these grounds that we built an activity to provoke people to observe and think routinely about the climate.

[1] Based on our experience of engaging with the public on weather and climate in the southwestern United States in the last 17 years as members of NOAA Regional Integrated Sciences and Assessment program and the extension specialist in climate science at The University of Arizona.

The Southwest monsoon

The North American monsoon is a regional feature that centers in northern Mexico and extends into the southwestern United States (mostly Arizona and New Mexico). Each year, hot and dry conditions in June give way to a rapid increase in humidity and thunderstorm activity in early July, which persists through September. The monsoon is driven by a change in the direction of mid- to upper-level winds from primarily a west to a southwest direction (Adams and Comrie 1997). The rapid increase in moisture supports the development of topographically driven diurnal convection across much of northern Mexico and the Southwest. The monsoon is a complex system whose variability in seasonal properties, like onset timing, total rainfall, and spatial heterogeneity generally increases away from the monsoon's core in northern Mexico (Vera et al. 2006). Year-to-year variability is high and spatial correlation can be low, depending on the season (Sheppard et al. 2002). The predictability of the monsoon at subseasonal and seasonal time scales is low (Castro et al. 2012).

The monsoon fantasy game was played in 2021 during one of the wettest monsoon seasons on record, with the south-central region of Arizona, around the Phoenix metropolitan, experiencing the largest wet anomalies (Fig. 1). The active monsoon was characterized by an increase in convective activity across the region in the beginning of July. By the end of July, rainfall across the major southwestern cities was much above average and near-record levels in Tucson. Above-average rainfall persisted into mid-August, when precipitation activity subsided. Late August and September were relatively dry.

Monsoon Fantasy Forecasting game

How the game worked. The objective of the monsoon fantasy game was to score the most points by accurately forecasting total rainfall at the international airports of five cities across the Southwest: El Paso, Albuquerque, Flagstaff, Phoenix, and Tucson (Fig. 1). Players made forecasts for July, August, and September at each city (15 total forecasts). These cities have long records and correspond to the major metropolitan areas in the region. To inform the forecasts, histograms of the historical rainfall were presented as for each city and month along with the median and mean values (Fig. 2). Forecasts were required to be made at least 7 days before the first of each month to prevent leveraging information from weather forecasts. Players only scored points for the cities in which they made a forecast.

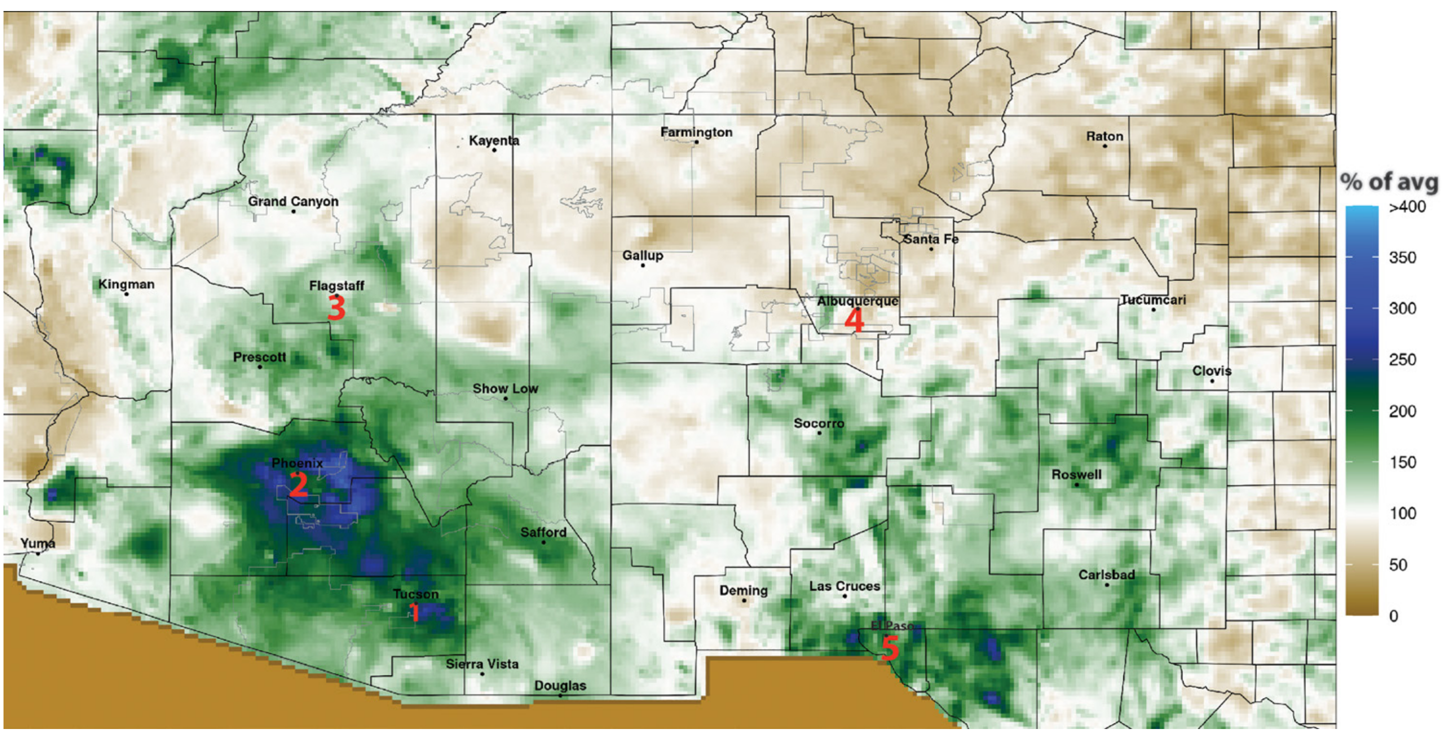

Fig. 1. Total monsoon season rainfall (1 Jul and 30 Sep) in 2021 as a percentage of the 1991–2020 average in the southwestern United States. Red numbers denote the cities in which monsoon fantasy players made monthly forecasts: 1) Tucson, 2) Phoenix, 3) Flagstaff, 4) Albuquerque, and 5) El Paso. Data source is from PRISM Climate Group.

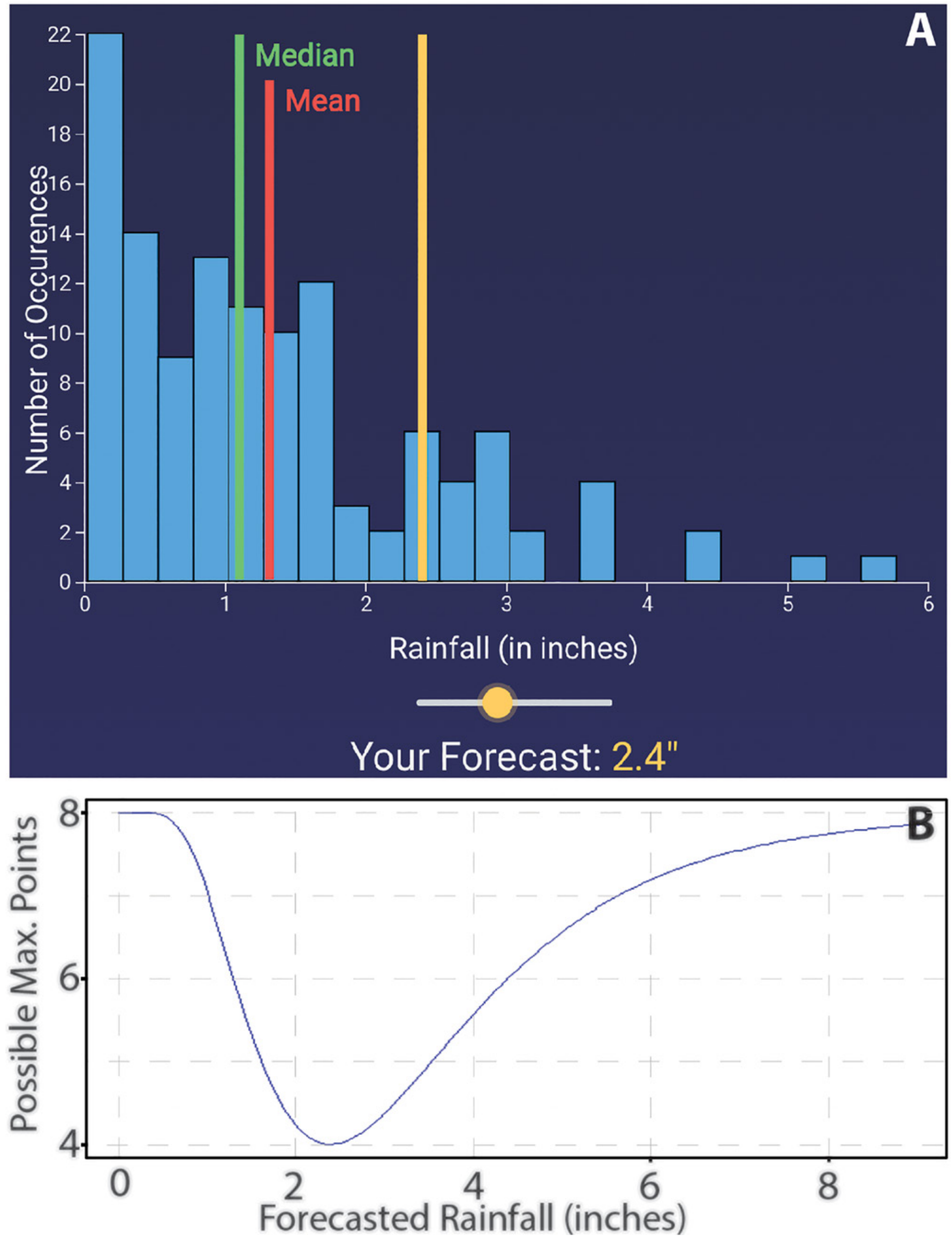

Fig. 2. **(a) The web interface for making a forecast for each city and month (this example is for July in Tucson). The blue bars represent the number of times the observed total monthly rain equaled the value on the *x* axis; the bars are in 0.25-in. increments. To make a forecast, the players slide the vertical yellow line left and right. (b) A graph of the modified lognormal distribution displaying the possible maximum points scored as a function of the player's forecasted rainfall. This distribution is based on Tucson's July rainfall where the mean is 2.4 in. (corresponding to the minimum possible points).**

Players accumulated points as a function of the likelihood and accuracy of the forecast. A less likely forecast was further from the mean of the historical rainfall data, and a more accurate forecast was closer to the actual rainfall for that month. The likelihood of the forecast determined the maximum possible points that could be obtained: the less likely the forecast, the more possible points a player could score. The accuracy determined how many of those points were scored.

Our two-part algorithm first determined the maximum possible points a player could score. For this, we modified a lognormal distribution to reflect the shape of the historical rainfall distributions and to make the possible points range from four to eight, with four points corresponding to the average and higher points moving away from the average, as shown in Fig. 3c. We refer the interested reader to the game's website for a more detailed scoring description,[2] with corresponding code on GitHub (Hoy et al. 2022). We set eight as the maximum possible points that could be scored each month at each station, a value we deemed reasonably large but not too large to result in a win based on one or a few correct risky guesses. Scoring the maximum points is unlikely based on the historical rainfall. To illustrate this, Fig. 2b shows that eight points are awarded for an accurate forecast less than 0.5 in. and greater than 9 in. in July at the Tucson International Airport (1 in. = 2.54 cm). Historically, total July rainfall less than 0.5 in. and greater than 9 in. occurred six and zero times, respectively, out of 74 years of data. The chance of scoring the maximum points is, therefore, approximately 8%. When making a forecast, players were able to see the possible points they could score based on their forecasted value.

[2] https://monsoonfantasy.arizona.edu/scoringdetails

The second part of the algorithm was accuracy, which was determined at the end of each month comparing the forecast to observed rainfall. Forecasts within one-fourth of a standard deviation of the actual rainfall received 100% of the maximum points. Forecasts within a one-half, three-fourths, or one standard deviation of the actual rainfall received 75%, 50%, or 25% of the maximum points, respectively. Forecasts more than one standard deviation from the actual rainfall received zero points. The standard deviation was derived from the historical data for each city and month.

We created a mobile-device compatible web platform that included a description of the scoring, an interface to make the forecasts, a dashboard to view the forecasts and the current points, and a ranked ordering of all the players' scores.[3] We used Facebook's React JavaScript framework to develop the user interface, as well as the D3 JavaScript library for data visualizations. To host the application, Google's Firebase was utilized and provided user authentication and the Firestore database to hold all the data for the project.

[3] https://monsoonfantasy.arizona.edu/home

Players had to create an account to play. They were also asked to create a profile by answering seven voluntary questions. The questions included how many monsoon seasons the person had experienced living in the Southwest, why they were interested in the monsoon, how often they looked at the weather forecasts during the monsoon, and their knowledge of the monsoon.

We incentivize participation by awarding automated weather stations with a retail value of $450.00 (U.S. dollars) to both the winner and the second-place finisher. Each month we emailed

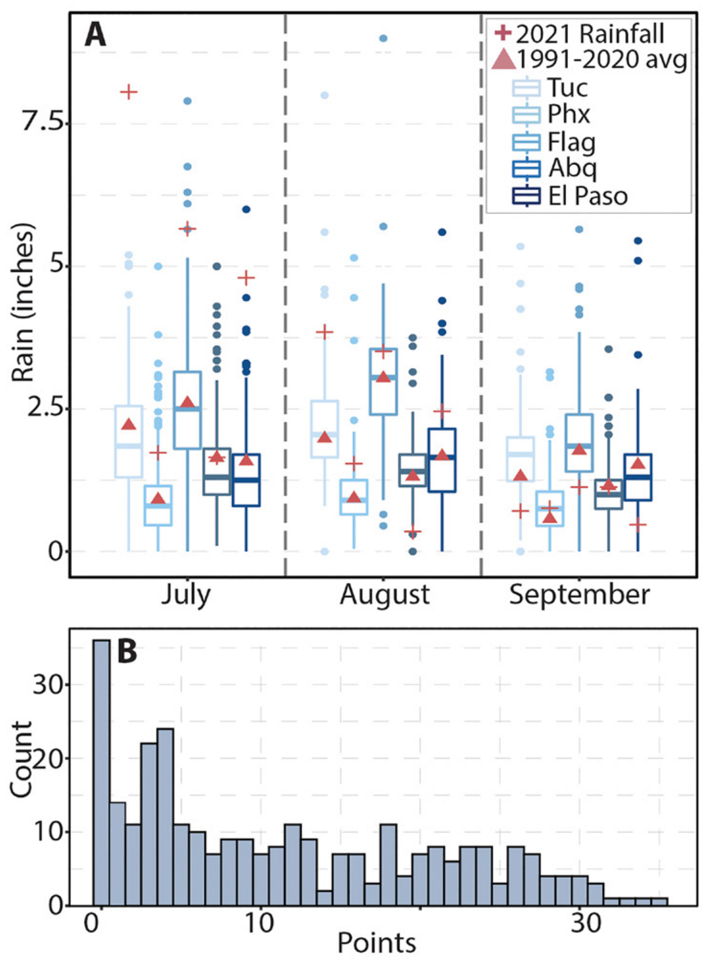

Fig. 3. (a) Averages of the players' forecasted values, the climatological average rainfall for the period 1991–2020, and the 2021 observed rain at each city and month. (b) Distribution of the total points scored.

monthly updates of the scoring with reminders to make forecasts. Team members discussed the game's results and the monsoon during a longstanding monthly podcast. Numerous media outlets helped showcase the game, including by the National Public Radio, The University of Arizona Press, and local TV and newspaper coverage.

Player profiles. A total 296 players submitted at least one forecast. Seventy players (24%) made all 15 forecasts, while 112 players (38%) only submitted forecasts in July. The average number of forecasts submitted was 8.4.

The majority of the players (88%) lived in Arizona. The players' main interest in the monsoon was curiosity (73%), while 16% stated their interest was driven because the monsoon affects their livelihoods. Half of the players self-identified as having a novice or advanced-beginner knowledge base of the monsoon. Only 20% of the players stated they typically sought out weather and climate information during the monsoon. These latter two points suggest that the game engaged people who are not the typical weather and climate enthusiasts.

Game scores. The game was launched during a historically wet first month of the monsoon. July was the wettest month on record at the Tucson International Airport (8.06 in.; its annual average is 11.22 in.), while the other four cities also experienced above-average rain (Fig. 3a). The wet beginning of the monsoon could have aided interest in the game. On the other hand, the large deviations from the July average led to low July scores, which may explain why 38% of the 296 players did not make forecasts during August or September (31 of the 36 scores of zero shown in Fig. 3b were scored by players who only made forecasts in July). At the end of the 3 months, there was a clear winner as well as a clear second-place finisher (Fig. 3b).

Participant feedback

In preparation for a second iteration of the game in May 2022, we sought feedback from the 2021 players in an online survey. We asked with fixed responses how playing the game influenced information-seeking activities and whether they would play again in 2022. We also asked in two open-ended questions ways to improve the game and what climate-related topics respondents wanted to learn more about. Because the survey was approximately 8 months after the end of the 2021 game, the results are only suggestive of how the game might spur additional learning. Nonetheless, the result are instructive for improving the game, stimulating learning, and informing future evaluations.

A total of 54 players from the 2021 season responded to the survey, roughly 18% of total number that submitted at least one forecast (296). Of the 54, 49 (91%) said they were likely to play in 2022. Figure 4 shows how the monsoon game may have affected the respondents' information-seeking behavior. Nearly two-thirds of the respondents recalled that the game altered their information-seeking behaviors, with nearly half of the respondents recalling paying more attention to forecasts. Additionally, 31 respondents (57%) provided feedback on monsoon topics they want to learn more about. The majority of the responses were related to the impacts of climate change on the monsoon, the dynamics of the monsoon system, and forecasting. Examples of each of these categories are, respectively, "How will climate change affect monsoon patterns… will monsoon moisture shift North-South?" "The effects of El Niño and La Niña on the monsoons," and "How much are we going to get this year?"

The engagement of games in climate services

The game leveraged curiosity around and anticipation for the monsoon season and it offers important considerations for future research and the development of climate services. A game approach can help overcome known barriers to climate services, including their limited reach into certain audiences due to the technical nature of the information (Dilling and Lemos 2011).

Consequently, climate services can privilege expertise. A second limitation is that climate services are most often oriented to inform decisions (Griggs et al. 2021). By focusing on decision-making outcomes, climate services overlook recent work in climate adaptation that emphasizes the importance of psychosocial dimensions (Noll et al. 2022), learning, and the engagement of citizen science networks (Crimmins et al. 2021; McMahan et al. 2021).

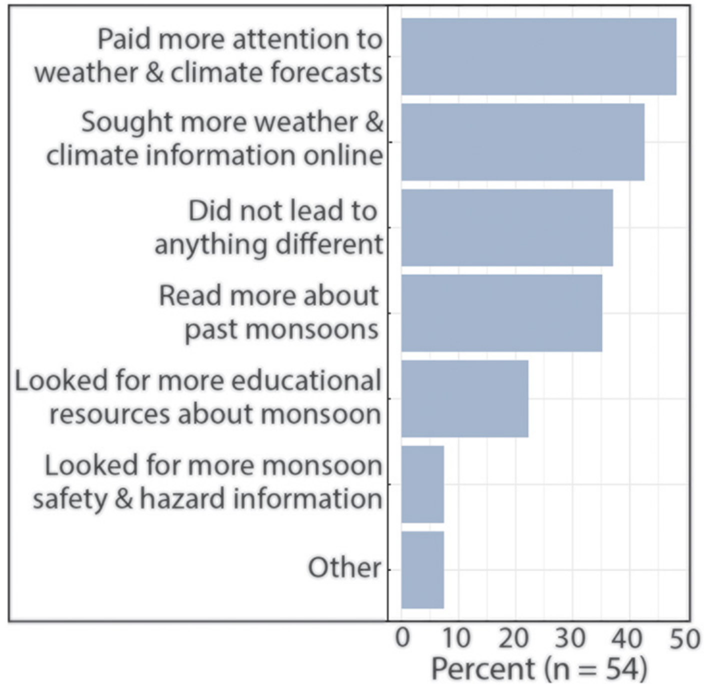

Fig. 4. Percentage of respondents who noted different ways playing the game may have influenced their information-seeking behaviors during the 2021 game.

On the other hand, games can increase the attention and popularity for the object of the game. This has happened in fantasy football, which has elevated engagement with American football (Drayer et al. 2010). The variability of the monsoon also means that experience and weather expertise are not necessary to play (and win). In fact, the winner was a new arrival to the region and was amused by her success (Brean 2021). Beyond that, the majority of the players self-identified as having a novice or advanced-beginner knowledge base of the monsoon.

Moreover, there is high potential for climate and weather games to improve our understanding of climate risk management, climate literature, and stakeholder engagement. For example, longitudinal studies could explore the learning effects of these games on multiyear participants and on how researchers iteratively improve game design. More broadly, climate services often present probabilistic information generated from ensembles of weather forecasts, seasonal climate forecasts, or climate projections. As a result, there is an element of communicating both risk and uncertainty. How people understand risk and make decisions considering uncertainty are active areas of research. In India, "rain betting" during the monsoon has been practiced for more than 100 years and has demonstrated that people are not "just victims of the unpredictability of nature, and that elements of agency, playfulness, and speculation co-exist with the rain-dependent economic system of agriculture" (Puri 2021, p. 115). Role-playing games have also been used to study climate-related concern, perceived seriousness, perceived likelihood, and psychological distance of tipping points (van Beek et al. 2022).

Games as learning tools are not new. They have been used to reveal decision logics and/or to explore the consequences of decisions in agriculture (Villamor and Badmos 2016) and for drought preparedness (Hill et al. 2014). These games are valuable, but perhaps struggle to be adopted outside of a classroom or an intervention. On the other hand, our monsoon fantasy game builds on the "ice-break" format where people predict the timing of an event, such as the first 100°F temperature of the year, and consequently monitor their predictions (Corpuz-Bosshart 2022; Pima County Public Library 2022). We hypothesize that stoking interest and awareness in the climate is a springboard to increase information-seeking behaviors and learning, and we have provided preliminary evidence that this occurred (see Fig. 4). If this proves true, then games like the fantasy monsoon forecasts may be scalable, reach diverse audiences, and have important impacts on learning. Perhaps games like this can be a partial response to the calls for new and innovated climate services to build more climate resilience societies (Jacobs and Street 2020).

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References

Adams, D. K., and A. C. Comrie, 1997: The North American monsoon. *Bull. Amer. Meteor. Soc.*, **78**, 2197–2214, https://doi.org/10.1175/1520-0477(1997)078<2197:TNAM>2.0.CO;2.

Alley, R. B., K. A. Emanuel, and F. Zhang, 2019: Advances in weather prediction. *Science*, **363**, 342–344, https://doi.org/10.1126/science.aav7274.

Brean, H., 2021: Professional forecasters have nothing on this Tucson monsoon watcher. Tucson.com, accessed 5 October 2021, https://tucson.com/news/local/subscriber/professional-forecasters-have-nothing-on-this-tucson-monsoon-watcher/article_8a50e324-252d-11ec-9b24-cf00edcf995d.html.

Casey, E. S., 1996: How to get from space to place in a fairly short stretch of time: Phenomenological prolegomena. *Senses of Place*, K. H. Basso and S. Feld, Eds., School of American Research Press, 14–51.

Castro, C. L., H. I. Chang, F. Dominguez, C. Carrillo, J. K. Schemm, and H. M. H. Juang, 2012: Can a regional climate model improve the ability to forecast the North American monsoon? *J. Climate*, **25**, 8212–8237, https://doi.org/10.1175/JCLI-D-11-00441.1.

Corpuz-Bosshart, L., 2022: Citizen scientists predict cherry blossom peak. myScience, accessed 1 April 2022, www.myscience.org/news/wire/citizen_scientists_predict_cherry_blossom_peak-2022-ubc.

Crimmins, M., B. McMahan, and W. Holmgren, 2021: Using volunteer observers to characterize fine-scale precipitation patterns across a western U.S. metropolitan area. *Int. J. Climatol.*, **41**, 4201–4214, https://doi.org/10.1002/joc.7067.

Dilling, L., and M. C. Lemos, 2011: Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environ. Change*, **21**, 680–689, https://doi.org/10.1016/j.gloenvcha.2010.11.006.

Drayer, J., S. L. Shapiro, B. Dwyer, A. L. Morse, and J. White, 2010: The effects of fantasy football participation on NFL consumption: A qualitative analysis. *Sport Manage. Rev.*, **13**, 129–141, https://doi.org/10.1016/j.smr.2009.02.001.

Fredrickson, B. L., 2013: Positive emotions broaden and build. *Advances in Experimental Social Psychology*, Vol. 47, Academic Press, 1–53.

Georgeson, L., M. Maslin, and M. Poessinouw, 2017: Global disparity in the supply of commercial weather and climate information services. *Sci. Adv.*, **3**, e1602632, https://doi.org/10.1126/sciadv.1602632.

Griggs, D., M. Stafford-Smith, D. Warrilow, R. Street, C. Vera, M. Scobie, and Y. Sokona, 2021: Use of weather and climate information essential for SDG implementation. *Nat. Rev. Earth Environ.*, **2**, 2–4, https://doi.org/10.1038/s43017-020-00126-8.

Hall, A., and G. Endfield, 2016: "Snow scenes": Exploring the role of memory and place in commemorating extreme winters. *Wea. Climate Soc.*, **8**, 5–19, https://doi.org/10.1175/WCAS-D-15-0028.1.

Hill, H., M. Hadarits, R. Rieger, G. Strickert, E. G. R. Davies, and K. M. Strobbe, 2014: The invitational drought tournament: What is it and why is it a useful tool for drought preparedness and adaptation? *Wea. Climate Extremes*, **3**, 107–116, https://doi.org/10.1016/j.wace.2014.03.002.

Hoy, D., and Coauthors, 2022: uaenvironment/monsoon-game-scoring-method, version 1.0.1. Zenodo, https://doi.org/10.5281/zenodo.6878318.

IPCC, 2022: Summary for policymakers. *Climatic Change 2022: Impacts, Adaptation, and Vulnerability*, H.-O. Pörtner et al., Eds., Cambridge University Press, 3–33.

Jacobs, K. L., and R. B. Street, 2020: The next generation of climate services. *Climate Serv.*, **20**, 100199, https://doi.org/10.1016/j.cliser.2020.100199.

Kwok, R., 2019: Can climate change games boost public understanding? *Proc. Natl. Acad. Sci. USA*, **116**, 7602–7604, https://doi.org/10.1073/pnas.1903508116.

Lejano, R. P., J. Tavares-Reager, and F. Berkes, 2013: Climate and narrative: Environmental knowledge in everyday life. *Environ. Sci. Policy*, **31**, 61–70, https://doi.org/10.1016/j.envsci.2013.02.009.

McMahan, B., R. L. Granillo, B. Delgado, M. Herrera, and M. A. Crimmins, 2021: Curating and visualizing dense networks of monsoon precipitation data: Integrating computer science into forward looking climate services development. *Front. Climate*, **3**, 21, https://doi.org/10.3389/fclim.2021.602573.

Noll, B., T. Filatova, A. Need, and A. Taberna, 2022: Contextualizing cross-national patterns in household climate change adaptation. *Nat. Climate Change*, **12**, 30–35, https://doi.org/10.1038/s41558-021-01222-3.

Pearce, W., B. Brown, B. Nerlich, and N. Koteyko, 2015: Communicating climate change: Conduits, content, and consensus. *Wiley Interdiscip. Rev.: Climate Change*, **6**, 613–626, https://doi.org/10.1002/wcc.366.

Pima County Public Library, 2022: Icebreak contest—Ice breaking on the Santa Cruz River. Accessed 1 April 2022, www.library.pima.gov/content/ice-breaking-on-the-santa-cruz-river/.

Puri, S. S., 2021: Gambling on the monsoon in the Indian desert. *GeoHumanities*, **7**, 113–130, https://doi.org/10.1080/2373566X.2021.1883992.

Risanto, C. B., C. L. Castro, J. M. Moker, A. F. Arellano, D. K. Adams, L. M. Fierro, and C. M. M. Sosa, 2019: Evaluating forecast skills of moisture from convective-permitting WRF-ARW model during 2017 North American monsoon season. *Atmosphere*, **10**, 694, https://doi.org/10.3390/atmos10110694.

Rooney-Varga, J. N., and Coauthors, 2018: Combining role-play with interactive simulation to motivate informed climate action: Evidence from the World Climate simulation. *PLOS ONE*, **13**, e0202877, https://doi.org/10.1371/journal.pone.0202877.

Sheppard, P. R., A. C. Comrie, G. D. Packin, K. Angersbach, and M. K. Hughes, 2002: The climate of the US Southwest. *Climate Res.*, **21**, 219–238, https://doi.org/10.3354/cr021219.

Smith, A. B., 2020: 2010–2019: A landmark decade of US billion-dollar weather and climate disasters. NOAA National Centers for Environmental Information Rep., 14 pp.

Sterman, J. D., 2011: Communicating climate change risks in a skeptical world. *Climatic Change*, **108**, 811–826, https://doi.org/10.1007/s10584-011-0189-3.

van Beek, L., M. Milkoreit, L. Prokopy, J. B. Reed, J. Vervoort, A. Wardekker, and R. Weiner, 2022: The effects of serious gaming on risk perceptions of climate tipping points. *Climatic Change*, **170**, 31, https://doi.org/10.1007/s10584-022-03318-x.

Veale, L., G. Endfield, and S. Naylor, 2014: Knowing weather in place: The Helm Wind of Cross Fell. *J. Hist. Geogr.*, **45**, 25–37, https://doi.org/10.1016/j.jhg.2014.03.003.

Vera, C., and Coauthors, 2006: Toward a unified view of the American monsoon systems. *J. Climate*, **19**, 4977–5000, https://doi.org/10.1175/JCLI3896.1.

Villamor, G. B., and B. K. Badmos, 2016: Grazing game: A learning tool for adaptive management in response to climate variability in semiarid areas of Ghana. *Ecol. Soc.*, **21**, 39, https://doi.org/10.5751/ES-08139-210139.

Wu, J. S., and J. J. Lee, 2015: Climate change games as tools for education and engagement. *Nat. Climate Change*, **5**, 413–418, https://doi.org/10.1038/nclimate2566.