

## Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations

**CLIMAS Investigators:** Ben McMahan, Mike Crimmins

**Additional Investigators:** Rey Granillo (Arizona Institute for Resilience); William Holmgren (Institute for Energy Solutions); Ramon Driesen (Bureau of Applied Research in Anthropology), Hsin-I Chang, Tony Lorenzo (Hydrology and Atmospheric Sciences)

**Graduate and Undergraduate Students:** Ryan Dennis, Patrick Bunn (Hydrology and Atmospheric Sciences); Gabe McGowan (School of Geography, Development, and the Environment); Mau Herrera, Benni Delgado, CJ Larsen (Computer Science); Dharma Hoy (Department of Mathematics)

**Key Partners:** Tom Dang, Ken Drozd, Marc Singer (NOAA – National Weather Service, Tucson)

**End Users:** NOAA – National Weather Service, Tucson and Phoenix offices; NWS Regional Climate Services Director; County Flood Control Districts; Pima County Office of Emergency Management; Oro Valley Police Department; Pima County Natural Resources Division; National Phenology Network

**Additional Resource Support:** National Weather Service, Tucson; College of Agriculture, Life, and Environmental Sciences, University of Arizona; Institute for Energy Solutions, University of Arizona; Office of Research, Innovation, and Impact, University of Arizona

**Project Dates:** 2018 – 2021

### Summary of Impact

**Understanding monsoon variability in Southern Arizona:** This project developed several climate services focused on the monsoon. An innovative monsoon data repository was developed to integrate different sources of monsoon data. This led to more detailed visualizations of rainfall patterns across Tucson and more a nuanced understanding of monsoon variability.

**Developing tools for monsoon preparedness and response:** Resulting products have been used by NOAA National Weather Service forecasters for training and real-time monitoring of precipitation and by the Pima County Office of Emergency Management to plan monsoon clean up and recovery efforts.

**Expanding coverage and knowledge transfer:** CLIMAS researchers created a replicable framework for data aggregation. Data coverage was expanded to Maricopa County and to rural areas (Pinal County and Mojave County) based on requests. The framework and protocol were also shared with other regions in the Southwest.

## Problem Statement

Monsoon precipitation is difficult to forecast and analyze. Daily and seasonal precipitation are commonly used, but other sources of data, such as citizen science monitoring, could be used to make a higher resolution and more accurate monsoon assessment framework.

## Research Focus

Tucson has dozens of observations collected by these networks, along with datasets based on radar and weather models. A central monsoon data repository forms a dense network of observations, facilitating innovative visualizations, and offering an unparalleled high-resolution view of regional precipitation patterns.

## Project Activities

**Meetings:** Iterative discussions about monsoon data with project partners, through meetings presentations, and workshops.

**Tool development:** Development of prototypes of for the monsoon visualizer, mapping tool, and station summaries; incorporating feedback from partners.

**Research design:** Documenting the process of developing monsoon tools and sharing this data protocol, code, and data.

## Project Outputs

### ***Datasets and Tools:***

[Monsoon Data Visualizer](#): Shows current monsoon precipitation patterns. Design based on specific requests from National Weather Service and other emergency management stakeholders. They want next-day decision support tools for post-event management – researchers designed the viewer with this application in mind.

[The Southwest U.S. Summer Monsoon Season Precipitation Mapping Tool](#): A near real-time monsoon season precipitation mapping system. Maps show total precipitation, intensity, and frequency of precipitation events of the summer monsoon season across Arizona and New Mexico including. Maps are updated once a day from June 15 - September 30th.

[Monsoon Season Station Summaries](#): Provides temperature and precipitation data for the monsoon season for individual weather stations across Arizona and New Mexico.

Monsoon Data GitHub Repository: A shared data and code repository, where project personnel developed and shared code (R and Python).

### ***Workshop:***

Pima County Office of Emergency Management – Hazard Mitigation Workshop. 2019. Co-host. Tucson, AZ. Breakout sessions to discuss information and research needs and priorities.

### **Public Engagement:**

[Southwest Monsoon Fantasy Forecasts](#): Developed a new online game for the public. The game was piloted in 2020 via the [Southwest Climate Podcast](#), hosted by M. Crimmins, Z. Guido, and B. McMahan. In the game, players estimate monthly rainfall totals for Tucson, Phoenix, Flagstaff, El Paso, and Albuquerque, and get points for how accurate and risky their forecasts are. This game received high levels of public and media interest and has continued every summer through 2024.

### **Peer-reviewed Publications:**

Crimmins, M.A., B. McMahan, W.F. Holmgren, G. Woodard. 2021. Tracking precipitation patterns across a western U.S. metropolitan area using volunteer observers: RainLog.org. *International Journal of Climatology* 41(8):4201-4214. <https://doi.org/10.1002/joc.7067>

McMahan, B., R.L. Granillo, B. Delgado, M. Herrera, M.A. Crimmins. 2021. Curating and Visualizing Dense Networks of Monsoon Precipitation Data: Integrating Computer Science into Forward Looking Climate Services Development. *Frontiers in Climate* 3: 602573. <https://doi.org/10.3389/fclim.2021.602573>

### **Thesis:**

McGowan, G. 2019. Geospatial analysis and quality control of monsoon season precipitation data from citizen reporters near Tucson, Arizona. MS Thesis, Geographic Information Systems Technology, University of Arizona.

### **Presentations:**

[Exploring Monsoon Season and Current Weather Conditions with CLIMAS](#). 2021. Sky Island Alliance Coffee Break Series

[Monsoon Monitoring Tools from CLIMAS](#). 2021. NIDIS Southwest Drought Briefing.

The Southwestern Monsoon – Presentations and Q&A. 2018. CLIMAS Colloquium designed to anticipate questions about upcoming monsoon, summarize recent research, and coordinate CLIMAS activities for monsoon outreach.

Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations. 2018. Presentation to NOAA-RISA teams.

Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations. 2018. Pima County Multi-Jurisdictional Hazards Workshop, Pima County Office of Emergency Management.

Visualization & Analysis Tools for the North American Monsoon – Integrating Citizen Science Data and Observations. 2019. CLIMAS Colloquium.

### **Selected Scientific Findings:**

[Representing a better understanding of monsoon variability](#): The monsoon is highly variable, even within small geographic areas like Tucson metro or Pima County. Data and

visualizations from this project illustrate this variability based on daily totals or event totals. Rainfall is typically measured at specific weather stations. This project uses a grid-based approach (MRMS/PRISM) that combines data from multiple sources to create a more complete picture of monsoon rainfall across the entire area. The gridded data helps highlight the variability of the monsoon and compares how well it matches the measurements from individual weather stations.

### **Leveraged Funding**

*Supporting this project:*

- Office of Research, Innovation, and Impact, University of Arizona (\$25,000)

*Supporting new initiatives beyond this project:*

- Arizona Institute for Resilience, University of Arizona (\$43,438)
- Southwest Climate Adaptation Science Center, U.S. Geological Survey (\$64,724)

## **Societal Impacts by Category**

### **Connectivity:**

- A presentation at the Pima County Hazard Mitigation Workshop led to additional collaborative opportunities with the Pima County Flood Control Office and the Oro Valley Police Department. Both were interested in using the aggregated data as decision support for prioritizing post-monsoon cleanup and recovery.

### **Conceptual:**

- This project provided more detailed and nuanced understanding of the monsoon across Tucson, and other regions in southern Arizona. Aggregated data from multiple datasets provided an improved visualization of precipitation patterns across the metropolitan area of Tucson.

### **Capacity Building:**

- This project led to the formation of the AIREs Research Computing Working Group, co-led by Rey Granillo & Ben McMahan. This working group supported three graduate students, three early career researchers, and two undergrad students. They contributed to project design, revised data aggregation and visualization techniques, and brainstormed additional data analysis and proposal development opportunities. The project directly supported Gabe McGowan's MS Thesis.
- The replicable framework for data assimilation and aggregation developed by this project can be applied by others in any location with multiple and overlapping data sets. Researchers collaborated with NWS Phoenix office to apply this framework in Maricopa County, using the 2020 monsoon as a testbed.

- Researchers expanded data coverage to rural areas (Pinal County and Mojave County) based on requests to build out the dataset and to create a system (API) that gathers and organizes data from the Arizona Department of Water Resources that is not otherwise available.
- The monsoon visualizer has been used as a training tool for NOAA-NWS forecasters.
- The protocol for developing, cleaning, and organizing data for the Aggregated Precipitation Database for Southern AZ served as a prototype for database development at larger scales. Conversations with colleagues in New Mexico and Texas increased their capacity to apply a similar process in the Las Cruces, El Paso, and Ciudad Juarez region.

***Instrumental:***

- The Monsoon Visualizer provides near real time overviews of precipitation and has been used to aid in flood control, monsoon recovery, and forecasting monsoon events.
- The [National Weather Service's Monsoon](#) webpage cites and links to the Monsoon Visualizer, the Southwest U.S. Summer Monsoon Season Precipitation Mapping Tool, and Monsoon Season Station Summaries. Their monsoon tracker integrates station data with CLIMAS-developed maps and data for daily and seasonal monsoon tracking.

***On technical capacity:***

We're currently migrating our website to a new content management system, which provides a better end product, as opposed to our old monsoon tracker which is 10 -20 years old. So that's a good thing. But one major disadvantage is that there's very little programming that we can do on the back end to add the data sets we need to help track the monsoon. That's where CLIMAS gets involved and it's a big, key component of this. They have their own internal servers where they can bring in data and repackage it in a way that's actually useful, that we technically can't do. They bring a lot of technical expertise that we just don't have and we aren't going to be able to mimic.

-  
*Tom Dang, National Weather Service  
Tucson*