M I D W E S T

Drought Early Warning System (DEWS) Partners Meeting

Summary Report

August 20-22, 2024

Indianapolis, Indiana

Report Author

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Acknowledgements

This report summarizes the ideas and thoughtful participation of speakers and attendees of the 2024 Midwest DEWS Partners Meeting, held in Indianapolis, Indiana on August 20-22, 2024. We thank all those who attended and contributed to the event's success.

NIDIS would like to thank the following entities for their help in planning, supporting, and/or organizing the 2024 Midwest DEWS Partners Meeting: NOAA Central and Great Lakes Regional Collaboration Teams, NOAA National Centers for Environmental Information (NCEI) Central Region, NOAA National Weather Service (NWS) Central Region Headquarters, Midwestern Regional Climate Center (MRCC), U.S. Department of Agriculture (USDA) Midwest Climate Hub, NOAA NWS Indianapolis Weather Forecast Office (WFO), Illinois State Climate Office, and the University Corporation for Atmospheric Research. Thank you to Dr. Jonathan Sleeman from the USGS Midcontinent Region for reviewing the document.

The report resulting from the 2024 Midwest DEWS Partners Meeting reflects the dialogue and discussion of attendees and does not represent official Administration policy or position, or an official policy or position of the individual organizations/agencies represented at the meeting.

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Introduction & Background

Precipitation extremes in the Midwest have a major impact on the region's resources, economic sectors, and residents. Over the last century, precipitation trends in the Midwest have been moving towards wetter conditions and fewer droughts than the region experienced in the early 20th century. However, the Midwest has still felt adverse impacts of recent droughts, particularly the widespread events in 1988 and 2012. Within the last decade, significant events occurred at a smaller scale across the region. These events include Missouri's flash drought in 2018, Iowa's multi-year drought from June 2020-May 2024, Minnesota's drought of 2021, and Ohio's flash drought in the summer and fall of 2024.

Drought in the Midwest can have many adverse impacts including limited barge transportation on major rivers (including the Mississippi River), decreased agricultural and livestock production, challenged municipal water supply and quality for both surface and groundwater, increased fire risk, limited water and altered habitat for ecosystems, and reduced productivity for hydropower.

In February 2016, the National Integrated Drought Information System (NIDIS) and its partners launched the Midwest Drought Early Warning System (DEWS) in response to the 2012 drought, which highlighted the need for additional drought early warning and preparedness in the region. **The Midwest DEWS is a network of partners that share information and coordinate actions to help communities in the region cope with drought.** Partners are from Federal, state, and local agencies, tribal nations, academic institutions, the private sector, and other entities across the Midwest.

Since its launch in 2016, the Midwest DEWS network convened six in-person meetings to provide partners from across the Midwest the opportunity to network and learn from one another, share success stories and challenges, and assess outstanding needs and gaps related to drought preparedness. The in-person meetings also provide the opportunity to identify, from the ground up, collaborative paths forward to advance drought early warning in the region.

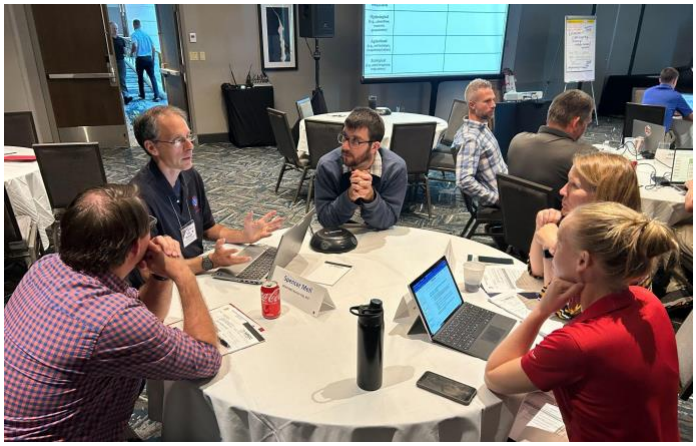
Meeting Goals

The 2024 Midwest DEWS Partners Meeting took place in Indianapolis, Indiana from August 20-22, 2024. This regional gathering provided the opportunity for partners in the Midwest DEWS to share and discuss ongoing drought-related activities, learn about new and innovative drought research and resources, explore emerging issues and opportunities, and identify collaborative paths forward to advance drought early warning and preparedness in the region.

The meeting goals included:

- Provide partners in the Midwest an opportunity to network and learn from one another on the topic of drought.
- Share success stories and challenges related to advancing drought early warning (which includes drought monitoring, prediction, response, planning/preparedness, and communication).
- Learn about new and innovative drought research and resources applicable to the Midwest.
- Explore emerging drought issues in the region and potential opportunities to address these issues as a regional network.
- Identify collaborative paths forward to advance drought early warning and preparedness across the Midwest.

Agenda Overview



The agenda featured seven topic-based sessions, each providing the opportunity for attendees to hear the latest research, learn about regional drought-related projects or efforts, discuss challenges to advancing drought early warning, and identify potential solutions to address these challenges. Many of the topics discussed were identified as priorities in the 2021-2024 Midwest DEWS Strategic Action Plan. The sessions were as follows:

- Plenary Sessions: Fifth National Climate Assessment and Regional Projects of Interest
- Session 1: NIDIS + Partner Updates
- Session 2: Drought and the Mississippi River
- Session 3: Addressing Drought Monitoring and Communication in the Midwest Under Complex Conditions
- Session 4: State Networking
- Session 5: Drought Monitoring
- Session 6: Ecological Drought in the Midwest
- Session 7: Meeting Reflection + Next Steps

The program included 27 talks from partners representing a broad range of Federal and state agencies, academic partners, and nonprofit organizations. There was a panel discussion on the Fifth National Climate Assessment, three facilitated tabletop discussions, and large group discussions. The full agenda is in Appendix A.

Copies of all presentation slides can be found on the meeting website.

Purpose of Report

The purpose of this report is to provide a quick and efficient overview of the in-person meeting, focusing on the key takeaways and opportunities from the meeting and how they will inform the Midwest DEWS and regional collaboration moving forward.

The appendices provide more details including the full agenda (A), list of meeting participants (B), an overview of the meeting evaluation (C), and a detailed table of the drought monitoring assessment (D).

Meeting Participants

Seventy people attended the meeting, with representation from all nine Midwest DEWS states (Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). Participants also represented a mix of organizations including Federal and state agencies, academic partners, and non-governmental and nonprofit organizations.

This meeting was held in conjunction with the Midwestern Regional Climate Center (MRCC)'s National Weather Service (NWS) Climate Services Workshop, attended by NWS personnel working on climate at local Weather Forecast Offices and River Forecast Centers in the region. While these were two separate meetings, there were several shared sessions for efficiency and expanded networking opportunities. Due to the collaboration with this workshop, most meeting attendees represented Federal agencies, and more specifically, the National Weather Service. The list of meeting attendees is in Appendix B.

Key Takeaways & Opportunities for Midwest DEWS Regional Collaboration

Drought Monitoring and Communication

Drought monitoring involves assessing data and impacts to determine the severity, location, and duration of drought events. Accurate drought monitoring can be very challenging but is crucial to understand, predict, and mitigate the impacts of drought including its effect on agriculture, water resources, ecosystems, and human health. In addition, effective communication of drought conditions and impacts can improve decision-making around drought, including triggering state, local, and/or individual actions to reduce potential damages.

States (e.g., state agencies, NWS offices, state climate offices) play a critical role in monitoring drought conditions to trigger actions within their state drought and/or water plan, and/or provide input into the U.S. Drought Monitor, which the U.S. Department of Agriculture (USDA) uses to determine eligibility for drought relief programs. Many entities responsible for drought monitoring and communication across the Midwest are part of the Midwest DEWS network, and therefore can provide valuable insights into data and information gaps across the region.

Through full and breakout group discussions, workshop attendees identified needs, gaps, and opportunities related to drought monitoring data and information, and drought communication, in the Midwest. Organizers asked them to identify weaknesses (e.g., what abilities are we lacking? Where do we struggle?) and opportunities (e.g., what are actionable solutions to achieve our goals? Where should we invest our time and resources to improve regional monitoring?) related to meteorological, hydrological, agricultural, and ecological drought monitoring.

Overall themes for **weaknesses and challenges** that emerged for all types of drought monitoring (meteorological, hydrological, agricultural, and ecological) included:

- A **higher spatial density of observations** is needed from mesonets and other observation networks for key variables including sub-daily precipitation, temperature, soil moisture, soil temperature, evapotranspiration, streamflow, and groundwater.
- **Access to accurate and accessible soil moisture, evapotranspiration, and groundwater data** are the most crucial data gaps for drought monitoring in the Midwest. These are critical variables to incorporate to quantify drought stress and the complete water budget. While some products and limited data are available for these variables,

many lack spatial and/or temporal density, are difficult to access and/or interpret, or do not accurately represent conditions on the ground.

- **More on-the-ground reports are needed** through systems like Condition Monitoring Observer Reports (CMOR) and CoCoRaHS Condition Monitoring to improve statewide monitoring and ensure various drought indicators accurately represent conditions.
- **Communicating drought and its complexities to the public can be very challenging**. For instance, it is difficult to explain why not all rain events will provide the same amount of drought relief (e.g., high-intensity rainfall events have limited soil infiltration/drought improvement; rain in the winter versus in the summer). Other communication challenges include interpreting weather and climate outlooks (e.g., confusion over terms like "elevated," "slight," and "percentile"), providing actionable drought information to the public, and conveying the overall cascading impact of drought.

Key Opportunities

Based on the needs and challenges above, as well as the others listed in the table in Appendix C, some key opportunities for drought monitoring and communication in the Midwest include:

- Support efforts to expand state mesonets in the Midwest that monitor for crucial variables like precipitation, soil moisture, and evaporation, leveraging national initiatives to help with this effort. These initiatives require state agency and private sector investment of time and resources to accomplish this effort. Share models of state-based support for increased observational monitoring (e.g., Missouri Hydrology Information Center) through the Midwest DEWS network.

- Host regional training(s) in collaboration with cooperative extension on how to become regular on-the-ground reporters to CMOR and CoCoRaHS Condition Monitoring,

leveraging the resources already available through the National Drought Mitigation Center (NDMC) and CoCoRaHS. Other entities that may be interested in this training include Master Gardeners, Naturalists, and USDA Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) staff.

- Share successful models to gather more on-the-ground reports through the Midwest DEWS network for other states to learn from. Successful models include efforts to broaden the use of CMOR in Missouri by the Missouri Department of Natural Resources (DNR) and the Indiana State Climate Office through their Indiana Drought Monitor Survey.

- Issue joint social media posts between state climate offices, local NWS offices, and NIDIS to amplify collective reach on social media for efforts like issuing Drought Status Updates or gathering more on-the-ground reports to CMOR or CoCoRaHS Condition Monitoring. Explore the use of "photo of the week/month" contests as well as humor to increase interest in this citizen science effort.

- To increase drought knowledge across more NWS WFO staff, NIDIS and state climatologists could work together to develop drought-specific training materials for WFOs to share with their staff. Also, state climatologists could increase in-person visits to WFOs in their state to build more relationships and knowledge around drought monitoring.

- Explore Forecast-Informed Reservoir Operations (FIRO) applicability in the Midwest to increase coordination among NOAA and dam/water operators to ensure operators incorporate NOAA forecasts and outlooks into water management decisions.

- Support efforts to improve soil moisture products, including those that merge in situ, satellite, and model data, in coordination with the National Coordinated Soil Moisture Monitoring Network (NCSMMN). In addition, through research and/or use, identify the most accurate soil moisture products for the Midwest.

- Catalog streamflow gages useful for drought monitoring (e.g., those that not affected by regulation or management). Discussions show this information is available via metadata, but having it available at the regional scale would aid more effective drought monitoring.

A full table of weaknesses and opportunities identified at the workshop for Drought Monitoring and Communications is available in Appendix D.

Ecological Drought

Ecological drought is an "episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems"[1]. There are many ways drought can negatively affect ecosystems across the Midwest, including low streamflow for aquatic ecosystems, lack of food or water for wildlife, increased disease in wildlife, less snow cover for habitat and overwintering, stressing young or established trees, and weakening of native species. Negative impacts on ecosystems can often have a negative indirect impact on humans as well, including impacts on food quality and supply, recreation, and tourism.

Many tools available for drought monitoring and forecasting focus on drought related to the human impact, water, or agriculture, rather than ecosystems. The 2021-2024 Midwest DEWS Strategic Action Plan identifies the need for more ecologically-relevant drought indicators to better monitor and mitigate the impact of drought on ecosystems across the Midwest.

To make progress towards improving monitoring for ecological drought and mitigating the impacts of drought on ecosystems across the Midwest, meeting attendees worked in breakout groups to identify needs, gaps, and opportunities around ecological drought. Facilitators asked them to identify the most pressing unknowns around ecological drought in the region, challenges around incorporating ecosystem impacts into routine drought monitoring (i.e., weekly or monthly), key opportunities to advance our understanding of ecological drought, and what partners should be involved moving forward.

[1] Crausbay, S. D., Ramirez, A. R., Carter, S. L., Cross, M. S., Hall, K. R., Bathke, D. J., Betancourt, J. L., Colt, S., Cravens, A. E., Dalton, M. S., Dunham, J. B., Hay, L. E., Hayes, M. J., McEvoy, J., McNutt, C. A., Moritz, M. A., Nislow, K. H., Raheem, N., & Sanford, T. (2017). Defining Ecological Drought for the Twenty-First Century. *Bulletin of the American Meteorological Society*, *98*(12), 2543-2550. https://doi.org/10.1175/BAMS-D-16-0292.1

Meeting attendees identified the following as some of the **most pressing unknowns**:

Assessing Drought Impacts	What are the long-term impacts of drought/flash drought on trees? How do these impacts interact with or are lessened or worsened by other stressors like flooding and higher humidity?
	How does flash drought impact ecosystems across the Midwest?
	What are the impacts (positive or negative) of periodic dryness versus multi-year drought on ecosystems?
	What are the cascading effects of drought on ecosystems across the Midwest?
Indicators, Tipping Points, and Triggers	What are drought indicators, triggers, and thresholds that work well for ecological drought monitoring? How can we use these to anticipate impacts on ecosystems and species?
	We need dry cycles/drought. If it was always wet or moist, then there could be harmful impacts. However, it is when we deviate too far from the cycle that we see negative impacts of drought. Where is this tipping point for various ecosystems across the Midwest?
Assessing Management Strategies	How can we anticipate and plan for ecological impacts? What are the management strategies? What time horizon is most useful for planning/management strategies?
Integration of Ecological Drought into the DEWS	Do natural resource managers have the data and information they need to make short-term and long-term decisions around drought?
Changing Climate	In a changing climate, how resilient are Midwest ecosystems?

While there is the desire to incorporate ecosystem impacts into routine drought monitoring, there were **various challenges** associated with this, including:

- Ecosystems are incredibly complex, and collaborations with ecologists are needed to understand the impact of drought on ecosystems across the Midwest. The Midwest DEWS does not include an extensive network of ecologists and/or biologists yet.

- There are a vast number of ecosystems in the Midwest. Also, ecosystems are not monoculture, so monitoring is difficult because different species experience different impacts.
- The feasibility of incorporating ecosystem impacts into routine drought monitoring (i.e., weekly or monthly) when the timescale of impacts is likely different (e.g., delayed response of species, annual assessments of species).
- For species that migrate, considering the impact of drought in different habitats.
- The difficulty of translating fundamental ecological research into operational monitoring and planning.

Key Opportunities

To address the many unknowns and challenges, meeting attendees identified the following list of key opportunities to advance our understanding of and resilience to ecological drought in the Midwest:

- Conduct a literature review on the impact of drought and drought-driven low flow to ecosystems across the Midwest.
- Increase partnerships between the weather/climate/hydrology community and ecologists and natural resource managers to understand their data and information needs related to drought and/or drought-driven low flow.
- Host session(s) on drought at ecology conferences in the region to build connections and begin to understand data and information needs around ecological drought. Potential conferences to attend include the Midwest Climate Adaptation Science Center (CASC) Annual Meeting, the Midwest chapter of the Native American Fish and Wildlife Society, the Ecological Society of America, and/or the Association of Fish and Wildlife Agencies.
- Once the DEWS builds relationships with ecologists and natural resource managers, explore the need to co-develop an ecological drought workshop in the Midwest.
- Document regional sources of ecological data (e.g., fish or wildlife population, tree health, bird surveys) for drought researchers to better understand the connection between drought and ecosystem impacts.
- Produce an assessment annually of the previous year's ecological drought impacts across the Midwest. Consider identifying "representative species" for various types of ecosystems in the Midwest to routinely track the impact of drought in the region.

There are many important groups and partners within the Midwest DEWS to include in ecological drought efforts moving forward. Those identified by the meeting attendees include:

- USGS Midwest Climate Adaptation Science Center (CASC),
- USGS Ecosystems Mission Area,
- Upper Mississippi River Restoration Program (relevant work: Ecological Status and Trends; Long Term Resource Monitoring),
- Great Lakes Restoration Initiative,
- Upper Mississippi/Great Lakes Joint Venture,
- Great Lakes Indian Fish and Wildlife Commission (GLIFWC),
- Tribal nations across the Midwest/Great Lakes region,
- U.S. Army Corps of Engineers Midwest Districts,
- USDA Midwest and Northern Forests Climate Hub,
- U.S. Fish and Wildlife Service,
- National Park Service,
- Argonne National Laboratory,
- Ecological Society of America,
- county conservation boards,
- state, tribal, and local fish and wildlife agencies/natural resource departments, and
- non-profits like the Nature Conservancy and Audubon Society.

Drought on the Mississippi River

The Mississippi River runs through ten states including Minnesota, Wisconsin, Iowa, Illinois, Missouri, Kentucky, Tennessee, Mississippi, and Louisiana, which includes six Midwest DEWS states. The entire Mississippi River watershed touches 31 U.S. states total and two Canadian provinces, draining 41% of the continental U.S.[2] Along its path, the river supports one of the world's largest commercial waterways, delivers drinking water for millions, supports recreation and tourism, and provides vital habitat for hundreds of species of fish and wildlife and other ecosystems.

For the last three years (2022, 2023, and 2024), the Mississippi River reached critically low water levels in the fall season due to widespread drought conditions across the Mississippi River watershed. Low water levels on the Mississippi River can have many negative impacts including limiting barge traffic and forcing restrictions on the amount of cargo barges can carry (therefore creating economic impacts), threatening municipal water supply due to access during low water levels or saltwater intrusion from the Gulf of America, and disrupting aquatic ecosystems and wildlife habitats.

Key Opportunities

Many partners present at the meeting represented various agencies or entities responsible for monitoring, forecasting, and/or communicating water levels, or managing its impact including NOAA's NWS River Forecast Centers (RFC) and WFO's, the U.S. Army Corps of Engineers (USACE), U.S. Geological Survey (USGS), state agencies, state climatologists, and the Nature Conservancy.

[2] https://www.americanrivers.org/river/mississippi-river/

Due to the significant impact drought and low flow can have on the nation's economy, communities, and ecosystems, and the relevance for the Midwest, workshop attendees identified the **need to increase coordination on an annual basis assessing drought and potential low-flow impacts on the Mississippi River**, similar to the coordination that happens each spring to analyze the potential risk for flooding between NOAA, USGS, and the USACE. From the perspective of the USACE, completing this **assessment every August** would be helpful to advise leadership ahead of the annual low-water inspection trips by the Mississippi River Commission[3] in mid- to late-August. Workshop attendees **suggest NOAA's National Water Center, NWS, RFC, NIDIS, CPC, USACE, and USGS coordinate to complete this annual assessment,** with the National Water Center as lead entity.

Other Key Opportunities

Broadening Midwest DEWS Partnerships

Partnerships are a critical component of a robust and successful regional drought early warning system. Partners expressed the value of being a part of the Midwest DEWS regional network as a place to learn, share, and brainstorm solutions to challenging drought-related issues.

Meeting attendees articulated a desire to focus on efforts to broaden partnerships within the Midwest for a greater impact and reach. In particular, targeting end users impacted by drought like those in agriculture (e.g., farmers, producers), industry, navigation, energy providers, etc. Or, expanding partnerships with established networks with a broad footprint across the Midwest, like cooperative extension.

To strategize the most effective ways to broaden the Midwest DEWS network, meeting attendees suggested a virtual or in-person **meeting focused on partnership building**. At this meeting, Midwest DEWS partners would specify the goal(s) to expand the network within the region, discuss the co-benefits of growing partnerships with particular groups, identify a narrowed-down list of partnerships to prioritize those that align with the specified goals, and develop a roadmap to move the partnership building effort forward.

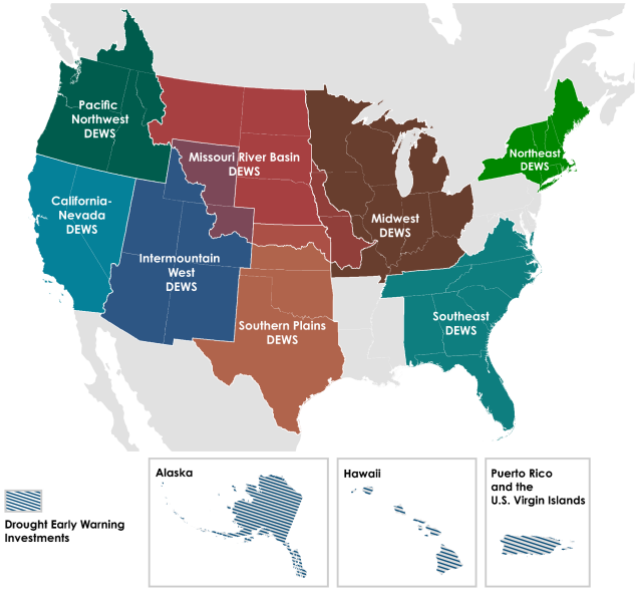
Meeting attendees also discussed another idea to broaden Midwest DEWS: the potential value of **incorporating topic-specific or user-specific meetings into regular Midwest DEWS meeting rotations**. For instance, co-developing a drought preparedness workshop with cooperative

[3] https://www.mvd.usace.army.mil/About/Mississippi-River-Commission-MRC/

extension, or co-developing an ecological drought workshop with the USGS and other partners that focus on ecology and natural resource management in the region. Targeting a particular topic of interest or user group would attract the attention of new partners, allowing the broader Midwest DEWS network to incorporate new perspectives and information.

Leverage and Learn from Other Regional DEWS

NIDIS has developed eight regional DEWS across the United States. Developing and implementing regional DEWS allows DEWS to respond to unique geographic and hydrologic circumstances, and address value-added information needs specific to stakeholders in the respective areas. However, there are similarities across the regions, which provides the opportunity to learn from other regions to become more drought resilient in the Midwest.



Meeting attendees identified **leveraging and learning from other regional DEWS on specific topics of interest** is an opportunity they'd like to take advantage of moving forward.

Specific efforts or topics meeting attendees were interested in learning more about include:

- Learning from the Southeast DEWS and the approach this region took to better understand and plan for ecological drought in their region, which included a January 2025 workshop specifically focused on drought and aquatic ecosystems.
- In an effort to garner additional support for state mesonet expansion, leveraging the Upper Missouri River Basin Data Value Study results to showcase the value of additional mesonet stations for improving drought and flood monitoring and forecasting.
- Learning from states like California that have advanced groundwater data and information to provide ideas on how Midwest products and tools for groundwater could be improved.

- Successful models for expanding the network and developing meaningful partnerships with various user groups like cooperative extension or the private sector.
- Successful models to increase on-the-ground reporting of drought impacts through CMOR or CoCoRaHS Condition Monitoring reports.

Underexplored Topics and Ideas

One of the goals of the Midwest DEWS Partners Meeting was to explore emerging topics and identify innovative solutions or opportunities to address these topics. Participants identified the following topics as of timely interest to many and worth further exploration:

- The **use of Artificial Intelligence (AI) in drought research** to analyze patterns for drought data and/or impacts in the Midwest. Improving our understanding of drought patterns and impacts would increase our ability to prepare the region for drought.
- **Develop drought frequency statistics** similar to the methods used for flooding (e.g., 1-in-500 year flood). Could these same methods apply to identify the "drought minimum probability" (e.g., 1-in-100 year drought) for locations across the Midwest? Developing this concept, which is widely used by the emergency preparedness community, could help convey the real-time severity of drought.
- **Improve our understanding of drought behavior and impacts in the Midwest for various temporal and spatial scales of drought**. Are there shifts in the timing of drought and impact during critical seasonal windows, and how is this impacting various sectors across the Midwest? For instance, how is the agriculture sector impacted by consecutive years of short-term drought in the summer? Are below-normal water levels each fall on the Lower Mississippi River like 2022, 2023, and 2024 a new normal? If summertime drought is becoming more common upstream, how will this impact the navigation sector and overall economy that relies upon the shipment of goods?

Appendix A: Agenda

NIDIS held the Midwest Drought Early Warning System (DEWS) Partners Meeting on August 20–22, 2024 in Indianapolis, Indiana. This regional gathering provided the opportunity for partners in the Midwest DEWS to share and discuss ongoing drought-related activities, learn about new and innovative drought research and resources, explore emerging issues and opportunities, and identify collaborative paths forward to advance drought early warning and preparedness in the region.

View the full meeting agenda on Drought.gov.

Appendix B: Meeting Participants

Last Name **: indicates virtual attendee*	**First Name**	**Affiliation**	**Primary Meeting Home**	
			DEWS Meeting	**NWS Workshop**
Alexander	Ross	University of Chicago and Argonne National Laboratory	X	
Beck	Jackie	The Ohio State University	X	
Bendorf	Josh	USDA Midwest Climate Hub	X	
Boyne	Jeff	NOAA NWS La Crosse, WI		X
Breon	Earl	NOAA NWS Indianapolis, IN		X
Britt	Mark	NOAA NWS St. Louis, MO		X
Brown	Kyle	NOAA NWS Northern Indiana		X
Bruschi	Audra	NOAA NWS Central Region Headquarters		X
Clark	Logan	NOAA NWS Wilmington, OH		X
Cogil	Craig	NOAA NWS Des Moines, IA		X
Cox	Kristi	Indiana Department of Natural Resources	X	
Crawford	Link	NOAA NWS Ohio River Forecast Center	X	

Last Name **: indicates virtual attendee*	**First Name**	**Affiliation**	**Primary Meeting Home**	
			DEWS Meeting	**NWS Workshop**
Darling	Lindsay	The Morton Arboretum	X	
Crow*	Liz	The Nature Conservancy	X	
DaSilva	Abram	NOAA NWS Ohio River Forecast Center	X	
DeLizio	Joseph	NOAA NWS Gaylord, MI		X
Eckberg	Roy	NOAA NWS Green Bay, WI		X
Eggleston	Keith	Northeast Regional Climate Center		X
Ehrman	Dick	Lower Platte South Natural Resources District	X	
Ford	Trent	University of Illinois	X	
Farmer*	Will	U.S. Geological Survey	X	
Frey	Trent	NOAA NWS Detroit, MI		X
Fuchs	Brian	National Drought Mitigation Center	X	
Funk	Ted	NOAA NWS Indianapolis, IN		X
Geelhart	Chris	NOAA NWS Lincoln, IL		X
Gross	Tim	NOAA NWS Davenport, IA		X
Grove	Glenn	Indiana Department of Natural Resources	X	
Hall	Tim	Iowa Department of Natural Resources	X	
Hall	Beth	Midwestern Regional Climate Center / IN State Climate Office		X
Hatch	Gene	NOAA NWS Springfield, MO		X
Herold	Brad	NOAA NWS Indianapolis, IN	X	
Holinde	Shane	Kentucky Mesonet and Kentucky Climate Center	X	
Hoving	Brandon	NOAA NWS Grand Rapids, MI		X
Javanmardi	Sara	Indiana Department of Natural Resources	X	
Johnson	Gary	USGS Central Midwest Water Science	X	

Last Name **: indicates virtual attendee*	**First Name**	**Affiliation**	**Primary Meeting Home**	
			DEWS Meeting	**NWS Workshop**
		Center		
Kerby	Elizabeth	Missouri Department of Natural Resources	X	
Kluck	Doug	NOAA National Centers for Environmental Information	X	
Kreiter	Amelia (Emily)	University of Minnesota	X	
Kuroski	Aidan	NOAA NWS Milwaukee/Sullivan, WI		X
Lashley	Sam	NOAA NWS Indianapolis, IN	X	
Li	Zhiying	Indiana University Bloomington	X	
Lindner	Garth	Indiana Department of Natural Resources	X	
Maier	Randy	Indiana Department of Natural Resources	X	
Mason	Bridgette	Wisconsin State Climatology Office	X	
Mayes Boustead	Barb	NOAA Climate-Ready Nation		X
McKenna*	Jim	USGS Great Lakes Science Center	X	
Mell	Spencer	NOAA NWS Kansas City, MO		X
Moore	Cody	NOAA NWS Indianapolis, IN		X
Nield	Joseph	NOAA NWS Indianapolis, IN	X	
Noel	James	NOAA NWS Ohio River Forecast Center	X	
Pearson	Austin	Midwestern Regional Climate Center / IN State Climate Office		X
Perry*	Bethany	NOAA		X
Peters	Molly	NOAA NWS North Central Forecast Center		X
Pettet	Crystal	NOAA NWS Indianapolis, IN	X	
Poulos	Sean	NOAA NWS Paducah, KY		X
Reaugh	Tom	NOAA NWS Louisville, KY		X

Last Name **: indicates virtual attendee*	**First Name**	**Affiliation**	**Primary Meeting Home**	
			DEWS Meeting	**NWS Workshop**
Rench	Thomas	NOAA NWS Ohio River Forecast Center	X	
Ryan	Mike	NOAA NWS Indianapolis, IN		X
Salzwedel	James	NOAA NWS Marquette, MI		X
Sandstrom	Joshua	NOAA NWS Duluth, MN		X
Satalino Eigsti	Kelsey	NOAA NIDIS and University of Colorado-Boulder	X	
Schillerberg	Tayler	USDA Midwest Climate Hub	X	
Sefcovic	Zach	NOAA NWS Cleveland, OH		X
Sleeman	Jonathan	U.S. Geological Survey	X	
Smith	David	Ivy Tech Community College	X	
Spielbauer	Christina	Indiana Department of Natural Resources	X	
Stumpf	Chris	NOAA NWS Indianapolis, IN		X
Todey*	Dennis	USDA-ARS/Midwest Climate Hub	X	
Wallace	Kirsten	Upper Mississippi River Basin Association	X	
Wasko	Renee	NOAA NWS Missouri River Forecast Center		X
White	Andrew	NOAA NWS Indianapolis, IN		X
Widhalm	Melissa	Midwestern Regional Climate Center		X
Wilson	Aaron	Ohio State University	X	
Woloszyn	Molly	NOAA NIDIS and University of Colorado-Boulder	X	
Wolverton	Anna	U.S. Army Corps of Engineers and NWS	X	
Zimmer	Chip	Kentucky Division of Water	X	

Appendix C: Meeting Evaluation

Meeting participants had the opportunity to provide feedback through a meeting evaluation. This evaluation assessed whether they believed the meeting met its intended goals, how likely the participant is to use information from the meeting, and provided the opportunity for the attendee to identify their most valuable takeaways from the meeting.

Participants rated the meeting an average of **9.3 on a scale from 1-10**. All participants said the length of the meeting (2.5 days) was "about right."

How effective was this meeting at accomplishing its intended goals?

Meeting Goals	Extremely Effective	Very Effective	Moderately Effective	Slightly Effective	Not at all Effective
To provide partners in the an opportunity to network and learn from one another around the topic of drought.	77%	23%	0%	0%	0%
To share success stories and challenges related to advancing drought early warning (which includes drought monitoring, prediction, response, planning/preparedness, and communication).	61%	31%	8%	0%	0%
To learn about new and innovative drought research and resources applicable to the Midwest.	38%	62%	0%	0%	0%
To explore emerging drought issues in the region and potential opportunities to address these issues as a regional network.	54%	46%	0%	0%	0%
To identify collaborative paths forward to advance drought early warning and preparedness across the Midwest.	62%	38%	0%	0%	0%

Some of the participant feedback on their valuable takeaways included:

- The importance of expanding/developing partnerships with other sectors and areas of expertise to understand how drought impacts their areas of study, and how the DEWS can better understand their needs and provide better information tailored to meet those needs.
- Need for increased collaboration on specific areas (e.g., ecological drought).
- Identified ideas for personal state drought plan revision.
- The talk on Drought.gov was very valuable and showcased many unknown features of the website.
- Excellent discussion on ecological drought and what partners could be involved in for raising awareness.
- Learned how differently each state and NWS office handles input to the U.S. Drought Monitor.
- More data is not the sole answer. Collaboration among aligned but different groups can yield new insights.
- It seems there is great potential to continue exploring ecological indicators and impacts, and pair these investigations with established drought methods.
- Found the breakdowns and discussions on types of drought (i.e. long term and short term) to be helpful along with ways of assisting the general public in understanding what each one means.
- I was new to this group and appreciated being in the room and learning about the challenges, successes, and future pathways that were presented.

Other meeting feedback, including both positive feedback and ideas to improve future meetings:

- It was a great opportunity to learn, network, and brainstorm.
- Positive feedback for having the joint meeting with the MRCC NWS workshop, and something to consider for future meetings as well.
- Desire for more breakout/tabletop discussions as the ones we had were very valuable/meaningful.
- It would have been beneficial to have a brief review of agricultural drought, as we had discussed meteorological, hydrological, and ecological drought but very little agricultural drought.

Appendix D: Drought Monitoring Assessment

Type of Drought Monitoring	Weaknesses	Opportunities

Consistent Themes Across All Types of Drought Monitoring	• **Need more mesonet data** for local-scale observations for key variables like precipitation, temperature, soil moisture, evapotranspiration, etc.
	  ○ Need easier access to mesonet data (for NOAA, through MADIS).
	  ○ Mesonet data, which is usually sub-daily, can also capture intensity of precipitation.
	• **Lack of on-the-ground reports** through systems like CMOR and CoCoRaHS.
	  ○ Sometimes conflicting reports.
	• Overall **communication of drought to the general public is challenging**.
	  ○ Explaining the complexity in how conditions can impact drought (e.g., rain in winter vs. rain in summer, heavy rainfall may not improve drought as much as public expects)
	  ○ Confusion over "elevated" "slight" "abnormally dry"
	  ○ Interpretation of outlooks.
	  ○ Providing actionable drought information to the public is challenging.
	• **Data access issues**
	  ○ Siloing of data sources.
		• Expand state mesonets in the Midwest; explore national initiatives to help effort.
		  ○ State investment of time and resources is needed.
		  ○ Leverage information produced from the Upper Missouri River Basin Data Value Study to showcase the value of additional mesonet stations and how it contributes to better drought/flood forecasting.
		• Host regional trainings in collaboration with cooperative extension to become regular reporters to CMOR and/or CoCoRaHS Condition Monitoring.
		  ○ Other entities to train: USDA NRCS, FSA, Master Gardeners and Naturalists, 4H groups.
		  ○ Utilize existing training information and templates from NDMC for CMOR.
		  ○ Utilize North Central Climate Collaborative network for cooperative extension connections.
		  ○ Include in training what to look for and what different levels of drought mean.
		• Showcase successful models for gathering more on-the-ground reports (e.g., Missouri, Indiana). Highlight how various efforts convey the "why" - why should someone spend their time submitting

	Overwhelming number of sources of data. ○ Replication of data/dashboards. ○ Multi-modal data streams may not integrate well. ● **Need an increased understanding of longer-term drought status and its impacts** for various locations (often focused on the short term but can have underlying dryness issues). ● NWS specific: ○ More NWS staff should focus or have knowledge around drought.	reports. ● Joint social media posts between NIDIS, state climatologists, and NWS offices to amplify reach for various efforts, such as sharing Drought Status Updates or gathering more on-the-ground reports through CMOR or CoCoRaHS. ○ Potentially use the idea of photo of the month/week contests, which are popular, for drought. ○ Utilize humor on social media to increase engagement. ● Prioritize adding more local and state agencies to state-based U.S. Drought Monitor weekly coordination groups. ● More outreach and education with the public on drought and its wide-reaching impacts, how to monitor drought, the USDM, etc. ○ Develop public messaging through social science research; make it relatable. ○ Re-evaluate wording to make it less confusing/jargony. ● Increase data sharing through an easily accessible repository "data lake." ● NWS specific: ○ Ask for more staff education and involvement in drought. ○ NIDIS and state climatologists work together to develop drought-specific training materials for WFO to share with their staff. Also, state climatologists could increase in-person visits to WFOs in their state to build more relationships

		and knowledge around drought monitoring.
Meteorological	• Lack of spatial density for precipitation observations. • Lack of temporal density: daily precipitation observations do not capture intensity. • Quality control issues and data inconsistencies. • Lack of data for winter precipitation including satellite estimations of snow water equivalent. • Current indices like SPEI do not consider snow drought. • Lack of accurate and precise long-term precipitation and temperature forecasting.	• Invest in quality equipment during the NWS Cooperative Observer Program (Coop) modernization process. • Encourage careful quality control of data from NWS Coop, mesonets and other data sources. • Increase accessibility of snow and snow water equivalent data for non-Western states. • Make analog information available (e.g., how does this drought compare to 2012?) • Explore existing tools like the "Extreme Forecast Index" and "Shift of Tails" from European models, which show advanced warning for storm systems.

Hydrological	• Limited groundwater information.
	  ○ Increased spatial density is needed.
	  ○ Lack of knowledge on how to find and interpret groundwater monitoring data.
	  ○ Mainly a state effort: lack of coherence at regional or national scales.
	• Lack of historical context for hydro variables (e.g., low flow thresholds, groundwater trends).
	• Many entities in the hydro space including USGS, USACE, NOAA - can make partnering and
		• State-based support and resources are needed to expand stream gage, groundwater, and reservoir data.
		  ○ Models: Missouri Hydrology Information Center, Iowa Flood Center
		• Build relationships with dam operators, private drinking water reservoir owners, state DNR for additional water data and information, as well as coordination.
		• Explore Forecast-Informed Reservoir Operations (FIRO) applicability in the Midwest to increase coordination among NOAA and dam/water operators to ensure NOAA forecasts

	coordination challenging. ● Limited water reservoir data. Very individual: potential to create network/regional scale information? ● Disconnect between dam operators and NOAA/NWS on maintaining water levels (e.g., are NOAA forecasts and outlooks used to make decisions?). ● Communication and interpretation of hydrological data can be difficult: ○ What does the 25th-75th percentile mean? Could mean different impacts depending on if you're talking about navigation vs. ecosystems, for instance. ○ How has management affected the levels and/or conflating drought impacts? ● NWS specific: ○ In the current River Forecast Center model, there is no direct way to incorporate soil moisture observations. ○ Need better access to the Hydrologic Ensemble Forecast System (HEFS).	and outlooks are incorporated into water management decisions. ● Explore feasibility of providing water reservoir data at the regional scale. ● Extend rating curves in coordination with USGS. ● Advance operational groundwater modeling, observation, and prediction with USGS. ● Catalog streamflow gages useful for drought monitoring (e.g., those that are not affected by regulation or management). Discussions show this information is available via metadata, but having it available at the regional scale would aid more effective drought monitoring. ● NWS specific: ○ Training for NWS staff on National Water Model advancements. ○ Develop relationship rules between SAC-SMA 'buckets' to account for current soil moisture observations.
Agricultural	● Limited soil moisture data ○ Significant differences in data from one product to another. ○ Most available data is modeled or satellite ET (not always accurate). ○ The best solution is having sufficient spatial resolution and a long enough record to	● Continue to make investments to improve soil moisture products - including those that merge in situ, satellite, and modeled data. Also, analyze "best" soil moisture product for the Midwest. ● Continue to support work on precipitation effectiveness to better

	properly characterize soil moisture in the same way we do precipitation. ○ Need increased understanding for the effectiveness of precipitation and subsequent soil infiltration. ● Limited evapotranspiration (ET) observations ○ Limited to modeled or satellite ET (not always accurate) ○ Lack of ET data makes it difficult to quantify water budgets and overall drought stress. ○ Need more in situ data; ET is difficult to measure/gages expensive. ○ Neet potential ET (PET) based on crop characteristics. ○ Need to improve evaporative demand products (lag, accuracy) ● Lack of general knowledge about drought and agriculture (crop type, timing, etc.) ○ How does weather/drought affect different crops - not all respond the same; also hybrid varieties make it difficult to assess droughts' impact. ○ Timing of heat/precip and crop development ● Lesser known animal/livestock impacts. ● Non-large scale ag system representation - need more specialty crop data/information.	quantify the amount of soil infiltration vs. runoff, and communicate these results through the Midwest DEWS. ● Develop/improve products for evapotranspiration (ET) that uses satellite data but also combines this with in situ data, or uses in situ for validation. ○ Add evaporation equipment to mesonet/other observing stations. ● Invest in monitoring infrastructure to increase ET and soil moisture observations across the Midwest. ● Increase engagement with the livestock industry to understand their data and information needs related to drought to improve research and product development. ● Build a more robust relationship with cooperative extension to increase understanding of agriculture cycle, crop development, drought impacts, and specialty crops. ○ NWS Specific: WFOs build connections with cooperative extension offices to increase understanding of local agriculture. ● Increase the use of cameras on stations to help capture the status of agriculture.

Ecological	• Lack of knowledge/terminology/impacts around ecological drought.
	• Complexity of ecological response to drought.
	  ○ Differences in plant/vegetation response.
	  ○ How do we quantify impacts? Are all impacts we are seeing negative or could some be positive?
	  ○ Seasonal timing of drought has different impacts on different ecosystems.
	  ○ Ecosystem response to drought is more delayed in some cases (e.g., trees: 2-3 years later)
	  ○ Heat stress vs. drought nuances.
	  ○ Urban and peri-urban community impacts.
	• Ecological drought impacts may be overlooked and/or difficult to incorporate in drought assessment.
	• Lack of observations with phenology under a changing climate.
	• Improve remotely-sensed data: increased resolution of NAVDI products.
		• Increase partnerships between the weather/climate/hydrology community and ecologists and natural resource managers to understand their data and information needs related to drought and/or drought-driven low flow.
		• Conduct a literature review on the impact of drought and drought-driven low flow to ecosystems across the .
		• Transfer this knowledge to the Midwest DEWS network, tying the impacts to the different levels of drought.
		• Use phenocams to understand higher-resolution ecosystem impacts.