CIROH CHRONICLE

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Colorado River, Utah
On the cover:
Ohio River Lock and Dam

CIROH supports NOAA and the National Weather Service with research strength to boost the U.S. capability for operational hydrological forecasting of streamflow, floods, droughts, and water quality. As a consortium of 28 academic, government, and commercial institutions, CIROH will enable transformational change within the hydrology community by advancing community water modeling and collaborative hydrologic research. CIROH integrates domain science in water with computer science, data science, and decision science. Leveraging the Alabama Water Institute and working closely with NOAA's Office of Water Prediction, CIROH builds partnerships across academia, government agencies, and the private sector.

Cooperative Institute for Research to Operations in Hydrology
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DIRECTOR'S MESSAGE

Welcome to the CIROH Chronicle, the annual report highlighting the impact of the Cooperative Institute for Research to Operations in Hydrology. CIROH's startup in 2022 and its amazing growth have been inspired by a shared vision, guided by an ambitious plan, enabled by detailed organization, and driven by incredible effort. This inaugural issue provides an overview of noteworthy research accomplishments, recognitions, and activities from CIROH's first full year.

I am thankful for the support and collaborative spirit from our NOAA partners, especially those at the Office of Water Prediction and the National Water Center, the latter of which is strategically co-located on The University of Alabama campus. The strong partnership between UA and NOAA laid the foundation for CIROH's early success and its accelerated ascension. Collaboration with the USGS and its Hydrologic Instrumentation Facility in Tuscaloosa, Alabama, has created new opportunities for connecting water observation, modeling, and prediction with communication and decision making. CIROH's research-to-operations enterprise is enabling the generation of new research results useful to water prediction practitioners in NOAA, USGS, and other government and private entities.

2023 was a busy year for CIROH as we built out our research portfolio of nearly 100 use-inspired projects that were responsive to NOAA and USGS research priorities and incorporated a unique CIROH objective of achieving operational benefits. CIROH is advancing the use of new water observing technologies and remote sensing platforms in operational hydrologic forecasting, improving the accuracy of water prediction systems, increasing the effectiveness and efficiency of data analysis and delivery to users, and enhancing the design and communication of forecasts. CIROH boosts NOAA's advancement of the Next Generation Water Resources Modeling Framework and is poised to support NOAA's development of the Next Generation Water Prediction Capability.

CIROH researchers made nearly 300 presentations and produced 32 journal articles. At the 2023 American Geophysical Union Annual Meeting, CIROH researchers made more than 85 presentations. CIROH's research outputs and impact are escalating at an incredible rate.

Complementing our research portfolio, CIROH successfully launched its education and training enterprise highlighted by the National Water Center Innovators Program Summer Institute, supported by CIROH partner CUAHSI. CIROH leveraged support from the National Science Foundation to create a Research Traineeship (NRT) for graduate students on the topic of water research to operations (Water-R2O). The Water-R2O NRT welcomed 15 graduate students from civil engineering and geography to a program that will help them build an interdisciplinary foundation of advanced knowledge and skills in water prediction, artificial intelligence, and decision science as they work toward a graduate certificate in operational hydrology. CIROH also launched a research experience for undergraduates in artificial intelligence for water forecasting. Additionally, CIROH held its first Developers Conference, with more than 200 participants attending training workshops, plenary presentations, and collaborative meetings on emerging topics in hydrologic forecasting. In total, CIROH's comprehensive approach to workforce development engaged approximately 3,000 undergraduate and graduate students, researchers, and practitioners. I look forward to seeing the depth, effectiveness, and reach of CIROH's education programs increase as we continue to expand and improve our innovative experiential learning opportunities.

I'm extremely honored to be building CIROH with NOAA, and the incredibly dedicated team at the Alabama Water Institute and across the CIROH consortium. Please enjoy reading about CIROH's early successes, and I encourage you to connect with us through CIROH's website, social media platforms, and national activities.

Steven J. Burian

Members

- University of Alabama
- Brigham Young University
- Colorado School of Mines
- Tuskegee University
- University of Alabama in Huntsville
- University of Arizona
- University of California San Diego
- University of Hawai'i at Mānoa
- University of Iowa
- University of Minnesota
- University of Saskatchewan
- University of Utah
- University of Vermont
- Utah State University

Partners

- Baron Weather
- Coastal Carolina University
- Consortium of Universities for the Advancement of Hydrologic Science, Inc.
- Dauphin Island Sea Lab
- Gulf of Mexico Coastal Ocean Observing System
- Jupiter Intelligence
- New Mexico State University
- Oak Ridge National Laboratory
- Pennsylvania State University
- RTI International Stevens Institute of Technology
- University of California, Davis
- University of Illinois Urbana-Champaign
- University of South Carolina

RESEARCH TO IMPACT

COOPERATIVE INSTITUTE

28
Consortium Institutions

411
Faculty and Research Staff

137
Postdocs and Graduate Students

INPUTS

2 Federal Sponsors

$84M
Research Funding

99
User-Inspired Projects

PRODUCTS

278
Presentations

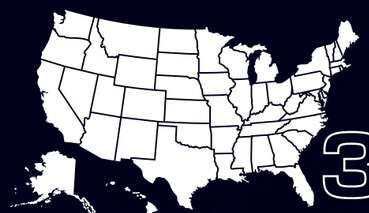
74
Sofware and Data Products

32
Published Journal Articles

IMPACT

Operational Benefits for NOAA and USGS

3K
Participants Engaged in CIROH Activities



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States Directly Benefiting from Research Products

CIROH's First Visiting Scholar Overcomes Big Data Challenges to Work with the National Water Model

Dr. Dan Ames is on a mission to make National Water Model data easy to access and use.

Ames, a professor of civil and construction engineering at Brigham Young University, has spent his life merging his passions for computer science and water science. He developed two key geographic information systems, MapWindow and HydroDesktop, which are used for environmental modeling, data visualization, and analysis.

Being the first CIROH visiting scholar at The University of Alabama, Ames with CIROH staff focused on "freeing the data" from the National Water Model forecasts. With his CIROH research, he aims to create information-producing tools that are as straightforward as weather reports for decision-makers at local, state, and federal levels to manage water basins.

Between the lines: Partnering with Google through Ames, CIROH is working to import historical forecasts into Google's BigQuery database, enabling easy search and retrieval of data by various parameters. Ames believes that aligning the needs of sponsors with the research goals of scientists is an incredible opportunity for CIROH.

Why it matters: Making National Water Model data accessible will empower researchers and decision-makers to manage water resources more effectively, ensuring public safety and resource sustainability.

During the 2023 Annual CIROH Science Meeting, Marouane Temimi, an associate professor at the Stevens Institute of Technology, received the CIROH Research to Operations (R2O) award. This prestigious accolade recognizes the most outstanding R2O accomplishments of CIROH researchers across the consortium.

Temimi Honored with CIROH R2O Award

Recognizing Excellence in Research to Operations

Why it matters: Temimi's project focused on advancing research in cold region hydrology, specifically by applying satellite remote sensing observations for modeling and mapping ice-induced flood inundation. The hydrologic models used in operational forecasting traditionally overlook the influence of river ice on streamflow in northern watersheds, leading to potentially inaccurate forecasts during ice breakup and onset periods. Through the implementation of an operational system for river ice mapping and monitoring, there has been a notable improvement in the ability to account for ice's significant impact on streamflow.

The last word: "The award is a tremendous honor for our team, and we deeply appreciate the support from CIROH, NOAA, the National Weather Service, and the National Water Center," said Temimi. "It serves as motivation to continue advancing our research to practical applications. The feedback from NOAA experts has been invaluable in enhancing our products, and we look forward to seeing our river ice monitoring tool used in decision-making, especially during critical breakup periods."

Tadd Bindas, a student from Pennsylvania State University, was honored with the 2023 CIROH Student Developer Award for his groundbreaking work on differentiable river routing and streamflow prediction. Bindas developed a fully differentiable, learnable Muskingum-Cunge routing model, which successfully recovered river parameters and can discern unknown functional relationships between channel characteristics and Manning's roughness coefficient. His ultimate objective is to enhance this river routing code to integrate seamlessly with NOAA's National Weather Service hydrologic modeling tools for predicting storm hydrographs.

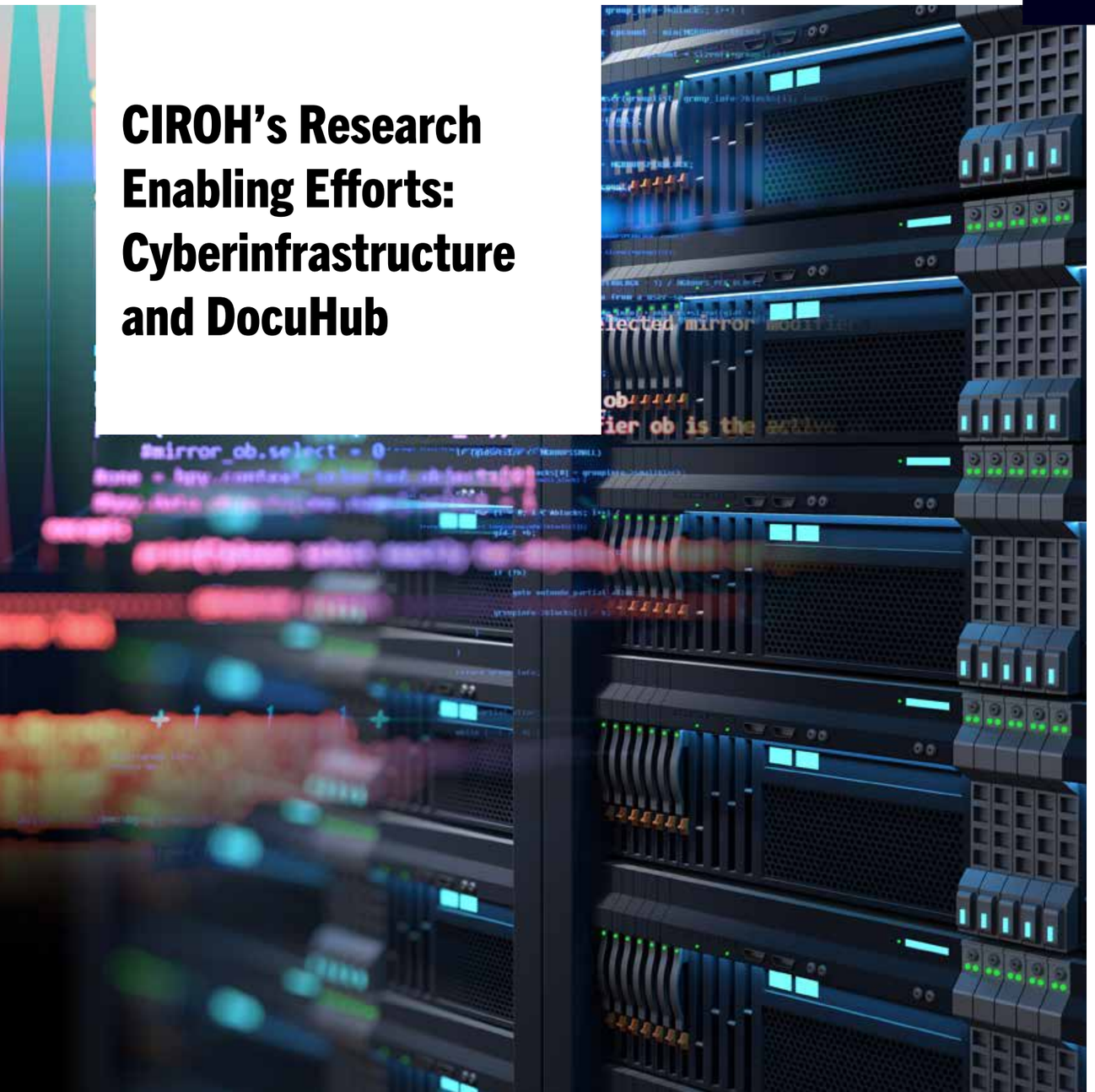
Bindas Recognized with Student Developer Award

Celebrating Innovation in Operational Hydrology

Why it matters: This award underscores the crucial role of students innovating approaches in hydrological research. Bindas' work not only contributes to more accurate streamflow predictions but also lays the foundation for future developments in hydrologic modeling.

Conference context: The award ceremony took place at CIROH's Developers Conference (DevCon) in Salt Lake City in May 2023, where Bindas was recognized for his exceptional contributions to hydrology research. His ongoing efforts promise to significantly enhance the nation's ability to forecast and manage water resources effectively.

CIROH hosts DevCon annually in the spring.



CIROH's Research Enabling Efforts: Cyberinfrastructure and DocuHub

EMPOWERING RESEARCHERS

Cyberinfrastructure Progress: Led by Arpita Patel, CIROH DevOps manager at The University of Alabama, and supported by partners at Lynker and across the consortium, the Cyberinfrastructure team has made significant strides in facilitating community contributions to the NextGen water resources framework. They have developed robust cloud and on-premises infrastructure to support CIROH consortium members in their hydrology research endeavors.

Innovation Highlight: "NGIAB (NextGen-in-a-Box) is a game-changer for water modeling technology," said Patel. This wrapper simplifies the deployment of the NextGen framework, enabling researchers to explore complex hydrological scenarios and generate valuable insights for water resource management and planning with ease.

DocuHub: The CIROH DocuHub, spearheaded by the Cyberinfrastructure team at The University of Alabama, has rapidly assembled comprehensive insights into CIROH's projects, services, and documentation. This system plays a pivotal role in democratizing access to National Water Model information.

Why It Matters: "This resource empowers team members, collaborators, and community partners by furnishing the knowledge necessary to enrich their understanding and contributions," said Dr. James Halgren, lead of CIROH's System Integration team at The University of Alabama. The DocuHub encourages contributions from all CIROH project participants, facilitating project documentation and linking to relevant GitHub repositories for ongoing work.

Looking Ahead: The System Integration team, in collaboration with Lynker, is developing the NextGen-Datastream, a daily running system that provides baseline research data for comparing and validating modeling and forecasting experimental outcomes. This initiative aims to bolster the reliability and applicability of National Water Model-based research efforts. For more information about Patel and Halgren's work, visit the CIROH website.

CIROH R2O

A unique aspect of CIROH is that it prioritizes research that may be transferred into impact, in particular research-to-operations (R2O). CIROH R2O aims to transform innovative insights into operational tools and strategies for real-world settings, enhancing water prediction capabilities, improving resource management, and benefiting society.

The Concept of R2O

R2O at CIROH is a dynamic process of continuous collaboration between researchers and operational teams. It ensures scientific discoveries and technological advancements move beyond academic papers to solve real-world problems. This involves setting standards and requirements, developing a playbook of best practices, optimizing workflows for efficient transitions, and building community-enabling infrastructure to foster innovation and technology transfer.

EMPOWERING RESEARCHERS

Why It Matters

R2O translates complex research into practical solutions, enhancing the accuracy, speed, and reliability of water predictions. This has significant implications for disaster preparedness, resource management, and environmental sustainability. By aligning research with operational needs, R2O ensures advancements in water prediction technology are quickly and effectively utilized to protect communities and support decision-making.

Progress and Achievements

CIROH has made substantial progress in advancing R2O, including:

- Playbook Development: A guide is under development for outlining standards, methodologies, and best practices for transitioning research into operations, serving as a resource for both researchers and operational teams.
- Workflow Optimization: Streamlined processes for testing and integrating new research findings into operational systems, minimizing delays and ensuring quick adoption of new technologies.
- Community-Enabling Infrastructure: Platforms, computational capacity, and networks for collaboration and knowledge sharing among researchers, operational staff, and stakeholders, sustaining innovation and goal alignment.
- Initial Success: CIROH has achieved ahead of schedule R2O success. Research developed an automated multi-satellite river ice mapping system being used by the National Water Center and northern River Forecast Centers that delineates and characterizes ice in rivers and water bodies. CIROH research also produced new evidence-based visual communication tools that increase equity and effectiveness of the NWS National Water Prediction Service decision support products. These are examples of the many CIROH projects that follow a co-production approach to enhance R2O.

Looking Ahead

Key future initiatives for CIROH's R2O program include:

- Staff Deployment and Development: Building multidisciplinary teams of experts dedicated to guiding research from insights to operational implementation, ensuring successful integration.
- Enhanced Collaboration: Strengthening partnerships with federal agencies and the private sector to expand the impact of the R2O program, enhancing overall effectiveness and reach.

Conclusion

The R2O program at CIROH advances water prediction and resource management by transforming research insights into operational tools. As CIROH continues to develop and expand R2O, it will drive innovation and ensure research efforts have a meaningful and lasting societal impact.

Improvement of Water Resources Prediction Systems

CIROH is dedicated to enhancing geospatial intelligence, refining data inputs, integrating probabilistic forcings, improving hydrologic models, advancing ensemble prediction and data assimilation techniques, optimizing operational workflows and tools, and rigorously quantifying uncertainties to extend the capabilities and applications of water resources predictions. A cornerstone of CIROH's community impact is the establishment of a robust water prediction system testbed and model evaluation framework, supported by critical collaborations with NOAA, NWS, NWC, USGS, and NOS. These integrated efforts leverage NOAA's extensive climate and water data, NWS's real-time weather inputs, NWC's cutting-edge hydrologic research, USGS's comprehensive hydrological datasets, and NOS's coastal data, all of which are essential for informed decision-making and fostering a resilient, water-secure future.

RT 1 | Focal Area 1: Water Observing Technology

CIROH's Research Theme 1: Focal Area 1 focuses on advancing water prediction systems through innovative water observing technologies and community collaboration. Key initiatives include:

- Advancing Hydrologic Data Collection: Efforts enhance capabilities in diverse regions like Vermont, Iowa, Alabama, Utah, and American Samoa through telemetered stream gauging, snow observation, water quality, and climate station installations, which improves accuracy in weather and streamflow predictions, reflecting CIROH's commitment to data-driven hydrology.

- Integrating Satellite and Drone Technologies: CIROH pioneers protocols across diverse water bodies for post-flood-event reconstruction and water quality monitoring and forecasting using satellite and drone technologies.

- Deploying Camera-Based Monitoring Systems: Systems in Utah and South Carolina provide real-time insights into water levels, supporting rapid response to hydrological events.

- Utilizing Small Unmanned Aircraft Systems for Flood Inundation Mapping: Enhancing operational capabilities during flood events.

- Enhancing Satellite Product Use: Initiatives like the CoastWatch Water Node strategy summit develop ideas to integrate satellite-derived data into water prediction workflows. Educational resources and workshops empower adopters to utilize remote sensing tools effectively, such as flood maps from satellite imagery.

By integrating cutting-edge technologies and fostering collaborative partnerships, CIROH enhances the spatial and temporal resolution of hydrological data, facilitating more accurate forecasts and informed decision-making in water resource management. Through these integrated efforts in water observing technology, CIROH strengthens its role as a leader in advancing geospatial intelligence, probabilistic forcings, and operational workflows, boosting the capability of the National Water Model.

Research Theme 1: Improvement of Water Resources Prediction Systems

RT 1 | Focal Area 2: Hydroclimate Inputs and Forcing

Research Theme 1: Focal Area 2 within CIROH is dedicated to advancing hydroclimate inputs and forcing mechanisms critical for enhancing community-driven water resources modeling. This area integrates cutting-edge technologies and data-driven approaches to reduce the uncertainty and accelerate the accuracy, speed, and resolution of water resource predictions, supporting sustainable water management practices.

Projects include:

- Advancing the Forecast Skill of Extreme Rainfall Events and Hydrologic Response Modeling: Enhancing understanding of storm patterns and their impact on hydrological systems, especially of extreme events such as atmospheric rivers, through sophisticated algorithms, improving the use of weather predictions in flood forecasts.
- Adaptation of Precipitation Super-Resolution and Data Fusion Techniques for Flood Forecasting: Using deep learning and data fusion to enhance the resolution and accuracy of precipitation data, enabling more effective prediction and response to flooding events.
- Enhancing Snow Accumulation and Melting Process Models for Water Supply Forecasts: Improving models for snow-dominated regions by integrating remote sensing and high-resolution weather data, enhancing forecast accuracy crucial for managing seasonal water supplies.
- Machine Learning for National-Scale Snow Water Equivalent Modeling: Pioneering machine learning techniques to predict snow water equivalent across the Western U.S., utilizing data collected from airborne and ground-based platforms.
- Contributing to the Updates to Precipitation Frequency Estimation in Atlas 14: Improving precipitation frequency estimates through advanced data processing, developing user-friendly tools for accessing critical hydrological data, and supporting effective water resource management and resilience planning.

These initiatives align CIROH's efforts with its broader objective of advancing hydrologic modeling capabilities and integrating innovative technologies into operational workflows. By enhancing inputs and reducing the uncertainty of predictive capabilities, CIROH supports informed decision-making and resilience against extreme weather events.

RT 1 | Focal Area 3: Hydrologic Modeling Improvements

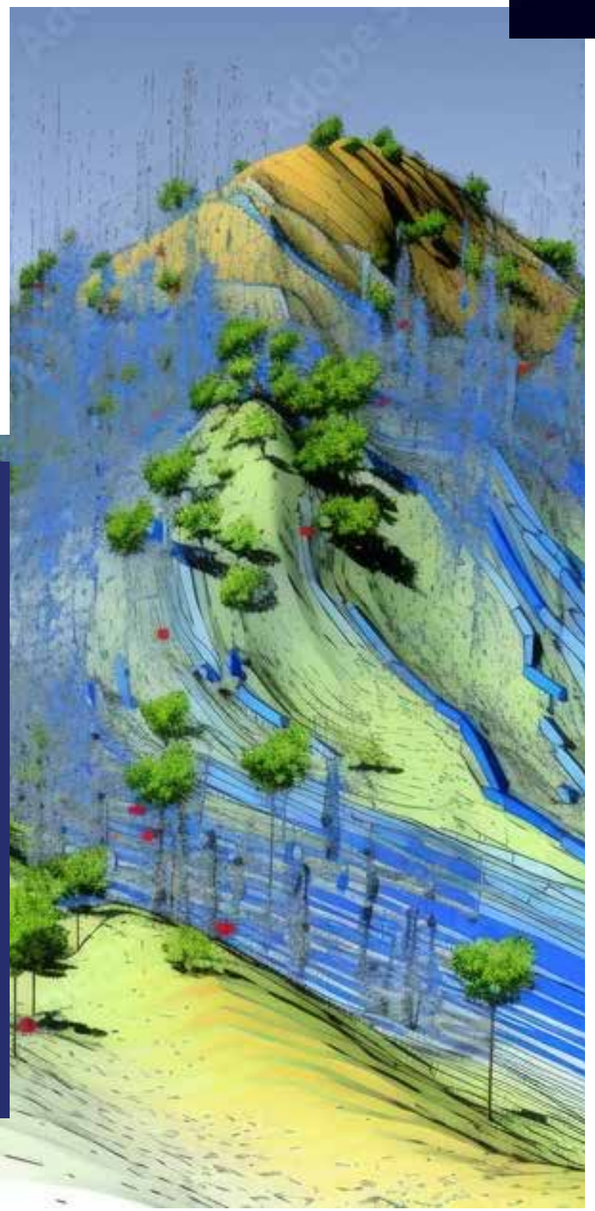
Focal Area 3 within Research Theme 1 advances hydrologic modeling to enhance water quantity and quality predictions at national scales. Integrating cutting-edge technologies such as satellite remote sensing and artificial intelligence with advanced hydrologic modeling techniques such as data assimilation, this area aims to improve predictive accuracy and resilience against hydrometeorological hazards.

Notable Achievements:

- Hydrometeorological Prediction Testbed for Water Resources Modeling: Establishing experimental protocols and collaborative modeling infrastructures to evaluate NextGen-based research advances, enhancing reliability for operational and research purposes.
- Data Assimilation and Fusion in Hydrologic Forecasting: Advanced data assimilation and deep learning improve precipitation forecast accuracy and use in hydrologic prediction, crucial for emergency response and water allocation decisions.
- Diagnostics of Hydrologic Variables and Transfer Functions in Hydrologic Models: Using machine learning and geospatial data, researchers enhance streamflow prediction accuracy, contributing to robust hydrologic modeling frameworks crucial for flood forecasting.
- Advancing Prediction of Drought and Low-Flow Conditions: This project leverages Python-based tools and big data analytics to improve understanding and prediction of low-flow conditions across the U.S., supporting sustainable water resource management practices.
- Riverine-Coastal Model Coupling for Water Quantity and Quality Prediction: Pioneering integration of inland hydrologic models with coastal dynamics enhances forecasting capabilities for coastal water quantity and quality, critical for resilience and hazard mitigation.

Aligned with RT1's mission, Focal Area 3 concentrates on refining hydrologic models to characterize droughts, low-flow conditions, and flood risks more accurately. By utilizing data assimilation techniques and innovative forecasting frameworks, researchers enhance water resource management decisions and community resilience.

Advancement and Acceleration of Community Water Resources Modeling



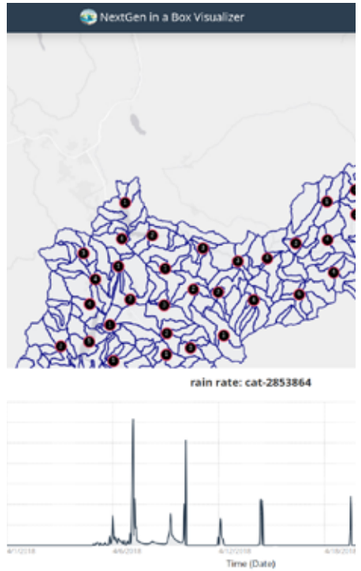
CIROH aims to advance community-driven hydrological modeling by enabling researchers with cyberinfrastructure tools and large-scale hydrologic modeling guidance. This effort provides researchers the ability to collaboratively incorporate biophysical, hydrological, and social process advances into a community water model to enhance prediction speed, accuracy, and resolution. A major contribution involves integrating these advancements into the developmental version of the Next Generation Water Resources Modeling Framework.

This initiative benefits significantly from the cyberinfrastructure tools and hydrologic data developed in RT1 and provided by our partners, including NOAA's comprehensive climate datasets and NWC's advanced research in hydrological modeling. The incorporation of USGS's extensive hydrological data supports the refinement and validation of our community water models. These collaborative efforts ensure our models are robust, accurate, and capable of meeting diverse water prediction needs.

RT 2 | Focal Area 1: Research Enabling Cyberinfrastructure

Focal Area 1 in Research Theme 2 develops and supports the cyberinfrastructure necessary for community water resources modeling. This involves creating and optimizing tools and platforms that allow researchers to efficiently deploy and execute complex hydrological simulations, with a focus on building robust, flexible, and scalable infrastructure that can handle diverse data sources and computational demands.

Significant Milestones:



- Versatile Framework Development: Pioneered NGIAB, a tool that optimizes NextGen hydrological simulations across different cloud platforms, ensuring flexibility and scalability.
- Cloud Computing Integration: Established robust presences on Amazon Web Services and Google Cloud Platform to efficiently manage data and enhance large-scale modeling workflow effectiveness and responsiveness.
- Automation and Integration: Implemented automation for complex simulations using GitHub Actions and 2i2c powered platforms, facilitating collaborative research and resource development.
- Community Engagement: The CIROH DocuHub acts as a central hub for developer documentation and hosts information from education programs and training workshops. This initiative aims to improve accessibility to large-scale hydrologic modeling and build expertise among researchers and practitioners.
- Infrastructure Support: Conducted monthly technical sessions and provided access to local servers and workstations. These resources are designed to support researchers in utilizing cyberinfrastructure effectively for their projects.

CIROH is enhancing cyberinfrastructure to integrate cutting-edge modeling frameworks, leveraging cloud and high-performance computing to accelerate hydrological prediction research, and fostering collaborative innovation.

Research Theme 2:
Community Water Modeling

RT 2 | Focal Area 2: A Community of Open-Source Development Platforms

Focal Area 2 in Research Theme 2 advances community-driven hydrological modeling through integrated model development and deployment. This involves fostering an environment where diverse hydrological models and techniques can be collaboratively developed, tested, and refined.

Core Initiatives Include:

- Diverse Model Integration: Enhanced forecast reliability via multi-model strategies, advancing diverse models and engaging the research community in testing them in the NextGen framework.

- NextGen Framework Deployment: Democratized cloud resources for collaborative model development, situating the NextGen Water Resources Modeling Framework in a hybrid cloud environment.

- Machine Learning Integration: Incorporated machine learning techniques to optimize model parameters and structure, improving predictive accuracy.

- Collaborative Innovation: Promoted effective water management and resilience planning through collaborative development on open-source platforms, enhancing the ability to address complex hydrological challenges across geographical scales.

These initiatives democratize computing resources and foster scalable, collaborative model development. Integrating machine learning with traditional hydrological models improves prediction speed, accuracy, and accessibility. By advancing these goals, CIROH is promoting collaborative innovation in addressing complex large-scale hydrological challenges.

Advancement and Augmentation of Hydroinformatics

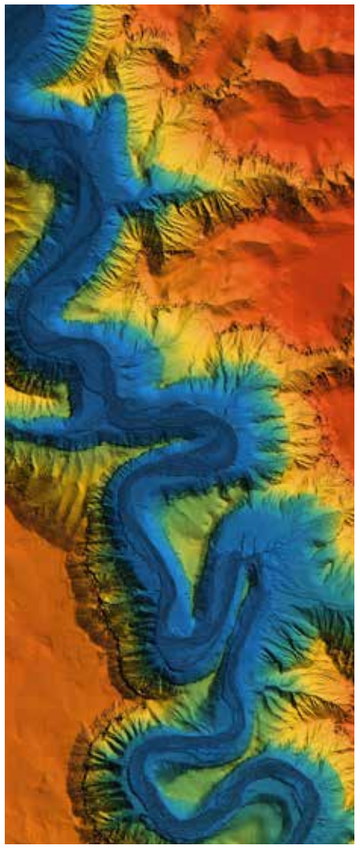
CIROH promotes Findable, Accessible, Interoperable, and Reusable (FAIR) data principles in its innovations in extreme data management, development of new informatics tools and community development platforms, creation of advanced user interfaces and experiences, and advancement of flood inundation mapping techniques.

Our partnership with NOAA and USGS ensures data management practices align with leading standards in operations. The National Weather Service contributes to the development of advanced user interfaces, while the National Water Center supports the creation of innovative informatics tools. USGS provides essential topographic and hydrological data for flood mapping, and the National Ocean Service supplies critical coastal and oceanographic data.

RT3 | Focal Area 1: Hydroinformatic Tools Development

Focal Area 1 in Research Theme 3, “hydroinformatics,” advances cyberinfrastructure vital for effective hydrological data management across operational and research domains. CIROH drives innovation in AI-driven analytics, real-time data integration, and advanced visualization tools.

Top Achievements:



- Extreme Data Management and Sharing: Advanced hydrologic information systems enhance data interoperability and real-time data integration, adhering to Open Geospatial Consortium standards.
- Intelligent Data Analytics and AI: CIROH integrated AI-driven services and web-based libraries to enhance geoprocessing, computation, and data analytics capabilities.
- Hydrologic Forecasting and Risk Assessment: Leveraging global climate models, CIROH improved hydrologic forecasting and assesses environmental risks, defining flow limits and exploring commercial opportunities.
- Digital Twin and Visual Analytics: Development of an immersive digital twin framework with AI-augmented visualization tools supports scenario-specific analysis and decision-making.
- Research Tools Portal: The CIROH Portal provides access to essential hydrological research tools for groundwater analysis, snow water equivalent mapping, and more.

Aligned with RT3’s objective to enhance hydroinformatics, Focal Area 1 drives the integration of advanced cyberinfrastructure. By leveraging AI, the cloud, and high-performance computing, CIROH enhances the speed, accuracy, and accessibility of hydrological predictions.

Research Theme 3: Hydroinformatics

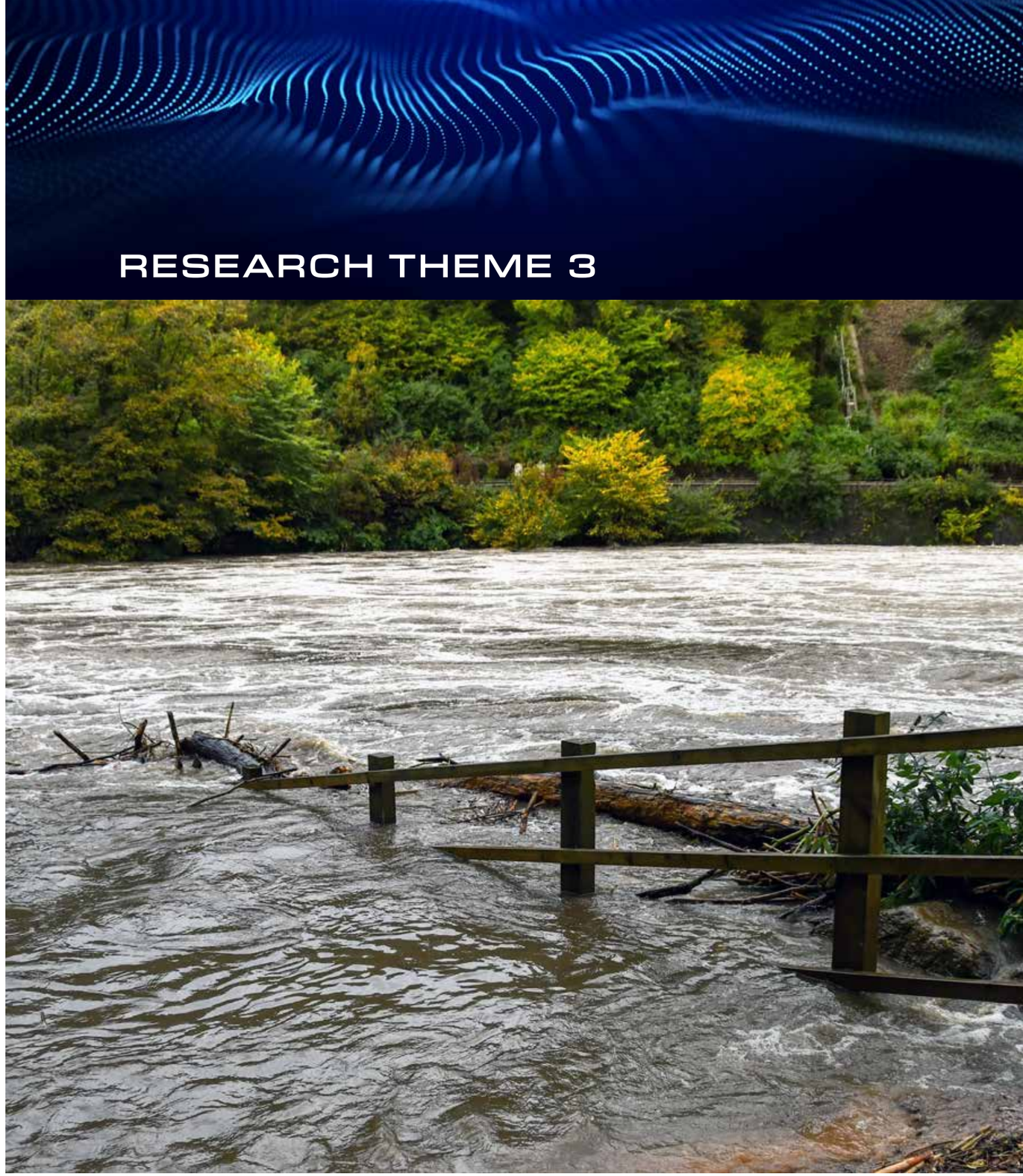
RT3 | Focal Area 2: Flood Inundation Modeling

Focal Area 2 in Research Theme 3 focuses on improving flood prediction models through advanced data management, machine learning, and geospatial analysis. CIROH's efforts aim to enhance the accuracy and utility of flood models, better understanding and mitigating flood risks.

Key Highlights:

- Channel Roughness and Morphology: Developed a remote sensing algorithm for flood mapping and analyzed channel characteristics using machine learning. Multiple flood solvers tested in North Carolina advanced predictive modeling.
- Floodplain and Natural Features: Using DEMs and geospatial data, extracted topographic features to understand floodplain connectivity. Calibrated hydrodynamic models in the Northeast to improve flood routing predictions.
- Geospatial Architecture: Identified key channel and floodplain properties with NOAA. Developed methods to obtain morphological attributes, enhancing flood modeling and FIM model performance.
- Marsh Model Testbed: Analyzed historical elevation models and satellite images to study marsh dynamics. Integrated core data and vegetation mapping to enhance flood impact understanding.
- Dam and Levee Breach Modeling: Refined physics-based breach evolution models and developed ML models for breach flow predictions. Tested against real-world data to improve flood routing schemes.
- Cold Regions Hydrology: Tested a satellite-based river ice mapping system and evaluated the National Water Models' streamflow simulations in ice-prone regions. Coupled models to predict ice formation and breakup, improving cold region flood forecasting.
- Machine Learning in Flood Mapping: Created machine learning models for flood mapping parameters and conducted intercomparison experiments. Integrated airborne LiDAR data to enhance computational efficiency and flood forecasting accuracy.

Aligned with RT3's goal to integrate advanced data management, machine learning, and geospatial analysis, Focal Area 2 enhances flood prediction models. CIROH leverages cutting-edge technologies and comprehensive data sets to improve floodplain management and mitigate flood risks.



Application of Social, Economic, and Behavioral Science in Water Resources

CIROH is coordinating national-scale integration of social and behavioral science research to uncover risk perceptions, user preferences, and forecast design needs and boost the operationalization of the information for all types of communities in the United States.

Our collaboration with NOAA ensures that our forecast design integrates comprehensive climate data and insights. The National Weather Service supports the operationalization of user preferences into practical forecast tools. The National Ocean Service provides critical coastal data to address specific needs of coastal communities. USGS's use of social science research contributions help uncover risk and inform decision-making processes.

RT4 | Focal Area 1: Impact-Based Decision Support

Focal Area 1 in Research Theme 4 enhances forecast design and risk communication to boost community resilience and support decision-making. It focuses on understanding risk perception, using innovative methods like serious games, and developing decision support tools for effective flood and drought risk communication.

Initiatives Include:

- Comprehensive Flood Risk Assessment: Integrated physical exposure and social vulnerability to create a high-accuracy flood susceptibility map in Harris County, Texas, demonstrating the importance of factors like elevation, land cover, and precipitation.
- Serious Games for Forecast Design: Engaged users and partners through focus groups, interviews, and post-crisis debriefings to enhance flood hazard messaging. Simulation-based experiments provide insights into public risk perception and behaviors.
- Improved Visual Forecast Products: Conducted focus groups to refine visual cues in forecast products. Collaborated with the Office of Water Prediction to integrate social science research into the development of the National Weather Service's new National Water Prediction Service mapping tool, reducing cognitive load and enhancing visual design.
- Flood Mapping Customized for Different Audiences: Engaged technical users and impacted communities, including tribal leaders and emergency managers, to tailor flood information to specific needs, which ensures that flood maps are user-friendly and effective during flood events.
- Optimized Flood Warning Information Sharing: Conducted science communication research to identify best practices for disseminating flood information. Developed moderator guides, focus groups, and surveys to enhance flood warnings' clarity and impact.

Aligned with RT4's mission to advance forecast design and decision support, Focal Area 1 improves community perception and response to flood and drought risks. Through interdisciplinary research, innovative tools like serious games, and user and partner engagement, CIROH enhances hydrologic risk communication and decision support systems, building more resilient communities equipped to manage and mitigate flood and drought impacts.

Research Theme 4: Forecast Design and Decision Support

RT4 | Focal Area 2: Advancing Forecasting Approaches

Focal Area 2 within Research Theme 4 develops innovative water forecasting strategies, approaches, and techniques that consider economic, legal, and policy frameworks, as well as unique socio-technical contexts. This involves creating comprehensive forecasting models that incorporate economic impacts, legal constraints, and policy requirements, and are tailored to the specific needs and conditions of different users. Initial applications under study by CIROH include infrastructure operations, water quality forecasting, informing agricultural producers, and drought information coordination.

Noteworthy Progress:

- Quantifying Forecast Value: Developed a framework to assess the economic and societal value of streamflow forecasts. Case studies in Fayetteville, NC, and St. Paul, MN, revealed how forecasts help local officials and residents make decisions and take protective actions, highlighting benefits like avoided property damage and improved emergency response.
- Forecast-Informed Reservoir Operations for Flood Risk Reduction: Implemented ensemble forecast-based models and Bayesian averaging in reservoir operations to improve flood risk management and conservation strategies, demonstrating effectiveness in uncertain hydrological conditions.
- Harmful Algal Blooms (HABs) Forecasting: Integrated advanced modeling techniques with AI-driven satellite data algorithms to improve HAB predictions. Focused on enhancing forecast accuracy in data-scarce watersheds, this project aimed to mitigate HABs' negative impacts on water quality and public health.
- Turbidity Loading Prediction: Collected high-frequency turbidity and meteorological data to develop predictive models for sediment levels in key water sources. Utilized airborne LiDAR mapping and refined sensor deployment strategies to support better reservoir management and mitigate sedimentation impacts on water quality and infrastructure.
- Forecast Product Delivery in Agriculture: Integrated soil sensor data, satellite imagery, and hydrologic models to support precision agriculture. Calibrated models for the Alabama-Coosa-Tallapoosa River Basin and collaborated with local farmers to provide decision support tools for managing soil moisture and irrigation, enhancing agricultural productivity and resilience.
- Drought Early Warning and Decision Support: Partnered with the National Integrated Drought Information System (NIDIS) and the National Water Center to improve drought prediction services. Defined research liaison activities to support alignment of CIROH research and operational needs leading to better preparedness and response to drought conditions, promoting sustainable water resource management.

Aligned with RT4's mission to advance forecast design and decision support, Focal Area 2 focuses on enhancing societal impacts of forecasts. Through interdisciplinary research, innovative modeling techniques, and stakeholder engagement, CIROH improves community capacity to manage and mitigate impacts of flooding, water quality impacts (e.g., HABs, turbidity), agricultural challenges, and drought conditions.

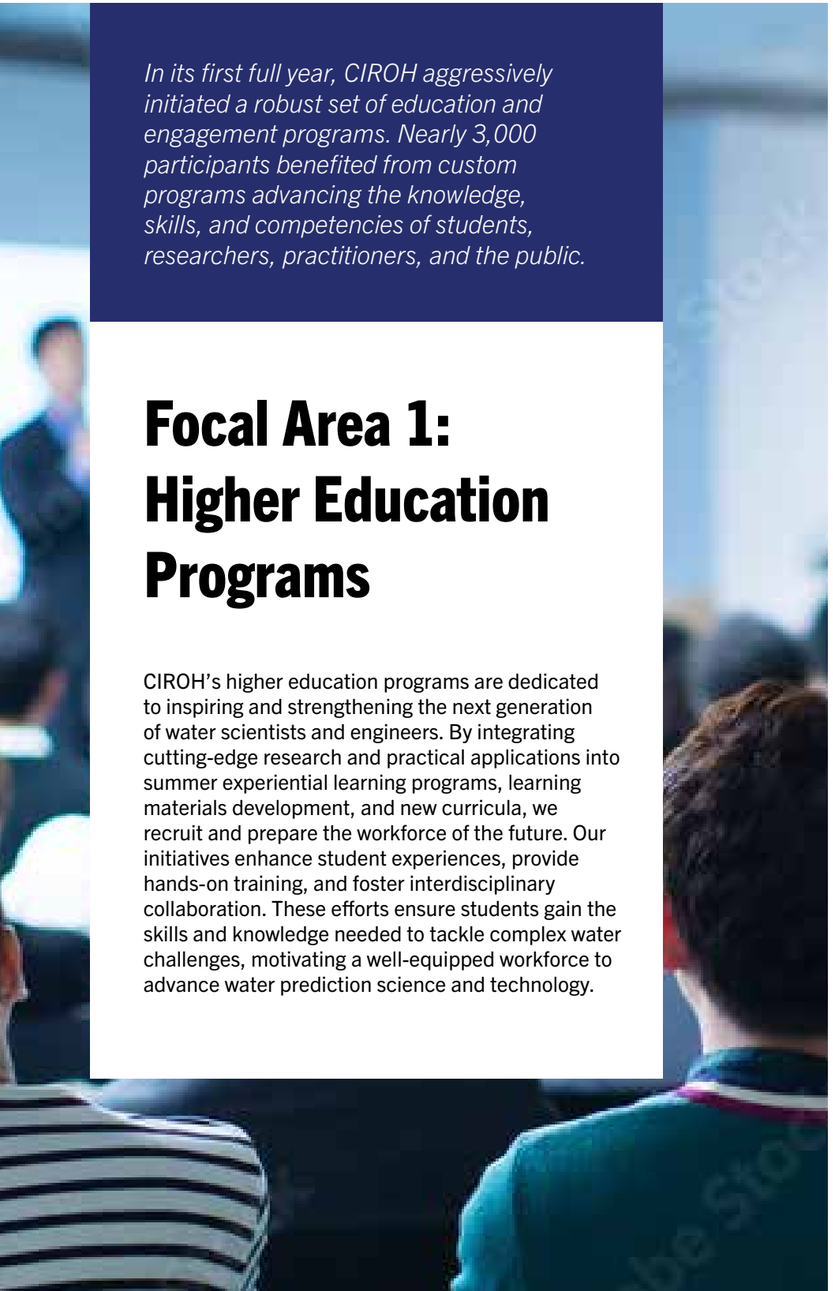
RT4 | Focal Area 3: Community Resilience

Focal Area 3 in Research Theme 4 enhances community resilience through innovative, equitable solutions. It addresses risk perception, decision support, and the implementation of integrated solutions (e.g., nature-based solutions) across time scales from seconds to centuries to mitigate flood impacts, emphasizing collaboration with local populations and incorporating diverse perspectives.

Significant Milestones:

- Coastal Nature-Based Solutions: Developed detailed hydrodynamic models of Mobile Bay and conducted extensive field surveys. Engaged partners and collected data on compound flood risks to integrate ecological and social science research. This project enhances community resilience through effective planning for nature-based solutions.
- Use of Traditional Knowledge to Implement Nature-Based Solutions for Flood Mitigation: Conducted a comprehensive literature review and engaged local communities in Hawai'i to assess flood risk perception and communication needs. Identified key regions and collaborated with users and partners to implement nature-based solutions tailored to local conditions. This initiative highlighted the role of community involvement and traditional knowledge in sustainable flood mitigation strategies.
- Equitable Climate Resilience in the Upper Mississippi River Basin: Analyzed regional stakeholder organizations and identified community hotspots vulnerable to flood and drought. Collaborated with community-centered organizations to support climate adaptation planning. This initiative emphasized equitable engagement and dissemination of research findings for regional resilience.
- Community Trust and Water Forecasting in Indigenous Communities: Modeled community trust and assessed water forecasting needs in Northeast Oklahoma's Indigenous communities. Collaborated with tribal leaders and organizations to address flood and drought issues specific to the region, demonstrating the value of building trust and understanding local contexts for effective water resource management.

Aligned with RT4's mission to advance forecast design and decision support, Focal Area 3 fosters community resilience through inclusive and equitable approaches. By integrating ecological, social, and cultural dimensions, CIROH's initiatives enhance communities' capacities to manage and mitigate water-related hazards. These projects contribute to building stronger, more resilient communities by addressing risk perception, promoting equitable solutions, and engaging diverse user groups in decision-making processes.



In its first full year, CIROH aggressively initiated a robust set of education and engagement programs. Nearly 3,000 participants benefited from custom programs advancing the knowledge, skills, and competencies of students, researchers, practitioners, and the public.

Focal Area 1: Higher Education Programs

CIROH's higher education programs are dedicated to inspiring and strengthening the next generation of water scientists and engineers. By integrating cutting-edge research and practical applications into summer experiential learning programs, learning materials development, and new curricula, we recruit and prepare the workforce of the future. Our initiatives enhance student experiences, provide hands-on training, and foster interdisciplinary collaboration. These efforts ensure students gain the skills and knowledge needed to tackle complex water challenges, motivating a well-equipped workforce to advance water prediction science and technology.

National Water Center Summer Institute

The National Water Center Innovators Program Summer Institute is a seven-week experiential learning program that brings graduate students together at The University of Alabama with faculty mentors, technical experts, and National Water Center scientists and operations staff. Since the first Summer Institute in 2015, the National Water Center and CUAHSI have provided a unique project-based learning program for more than 180 students, which has produced a number of important discoveries and advances in the National Water Model, flood inundation mapping, and water prediction systems in the United States.

First Cohort of CIROH's Operational Hydrology Graduate Training Program Begins

The University of Alabama's Water-R2O National Science Foundation Research Traineeship program has welcomed its first cohort, beginning their unique hydrologic science research and training journey. The Water-R2O NRT program unites master's and Ph.D. students from diverse water disciplines, provides experiential learning through internships, project-based learning, and study tours connecting with government and commercial partners, and equips them with the skills to meet the R2O needs of hydrologic researchers, forecasters, and decision-makers across government, private, and academic sectors.

CIROH Inspires the Next Generation with a Research Experience for Undergraduates

CIROH launched its first Research Experience for Undergraduates program, offering students from across the country the opportunity to collaborate with University of Alabama faculty and federal agency personnel on applying artificial intelligence to advance water forecasting. This program aims to equip students with essential water prediction skills for success in graduate school and the workforce.

Participants engage in research areas such as applying machine learning and process-based models to tackle big water data challenges and understand climate change impacts on water systems. They also gain experience in creating robust cyberinfrastructure, developing open-source tools for user interaction, and improving water information visualization to support decision-making processes.

Multidisciplinary Curriculum for Hydrologic Instrumentation

CIROH is developing a comprehensive hydrologic instrumentation curriculum to accompany the arrival of the new USGS Hydrologic Instrumentation Facility in 2024. Courses will cover four key topics: sensors, signal processing, power, and the Internet of Things. The curriculum is a certificate with a capstone. After piloting the program at The University of Alabama, CIROH will share the materials for adoption at other institutions of higher education.

Hydrologic Remote Sensing Certificate Program

CIROH is creating a hydrologic remote sensing curriculum program to build on recent scientific advances in remote sensing platforms and water observing technologies. The program will emphasize microwave remote sensing and cover surface water, groundwater, and water quality.

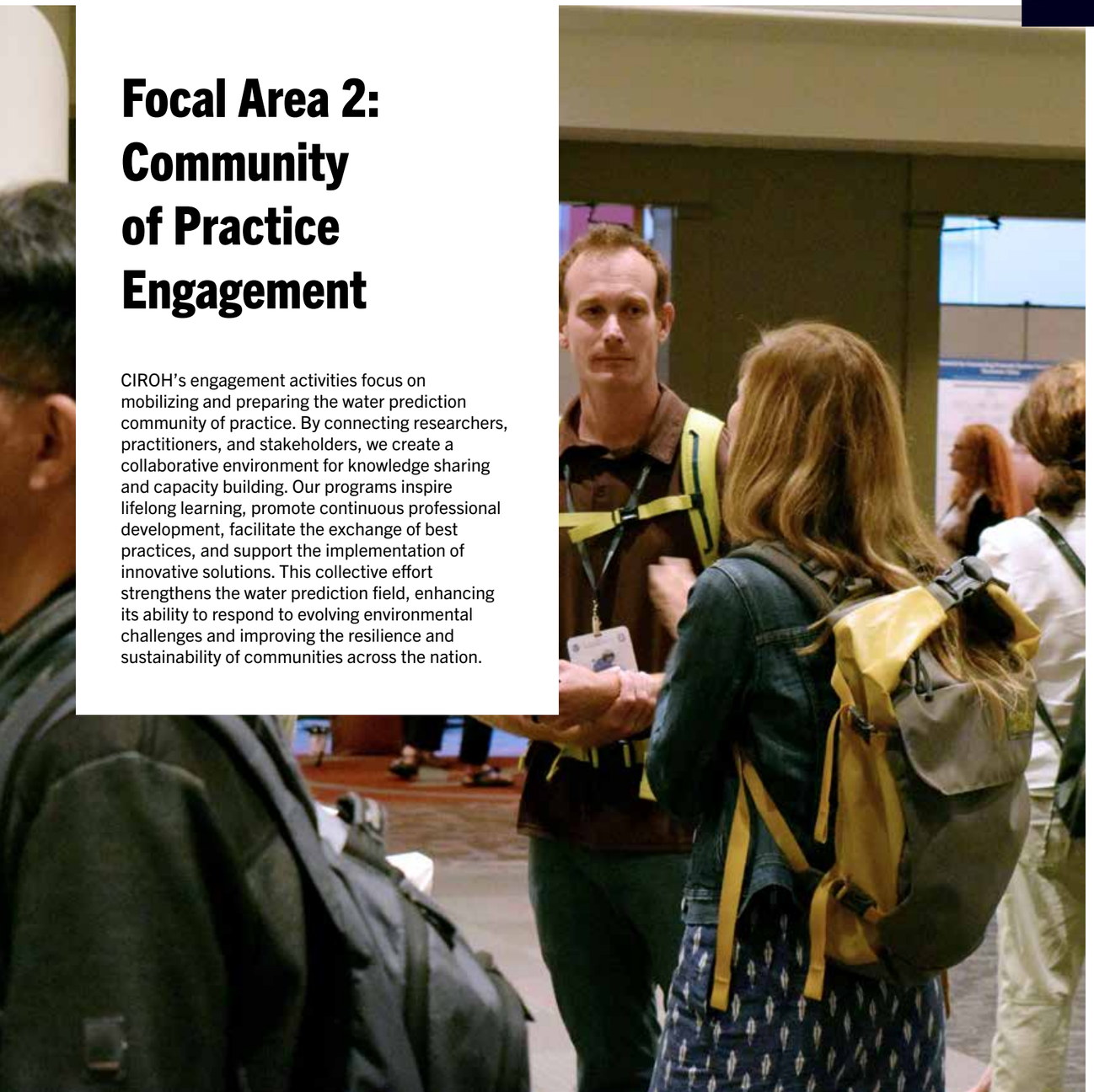
CIROH Supports HydroLearn Program to Develop Genuine Learning Experiences

HydroLearn is an established program with dozens of course materials in hydrologic science and applications. CIROH is supporting cohorts of faculty from across the United States to develop course modules following the HydroLearn hackathon approach and rigorous standards. The learning materials produced by participation in the HydroLearn program will target high-priority topics, employ examples, data, and tools from NOAA and USGS, and be made freely available.

EDUCATION & ENGAGEMENT

Focal Area 2: Community of Practice Engagement

CIROH's engagement activities focus on mobilizing and preparing the water prediction community of practice. By connecting researchers, practitioners, and stakeholders, we create a collaborative environment for knowledge sharing and capacity building. Our programs inspire lifelong learning, promote continuous professional development, facilitate the exchange of best practices, and support the implementation of innovative solutions. This collective effort strengthens the water prediction field, enhancing its ability to respond to evolving environmental challenges and improving the resilience and sustainability of communities across the nation.



CIROH Hosts Annual Science Meeting in Tuscaloosa

CIROH annually hosts at The University of Alabama its Science Meeting for more than 150 members of the water prediction research and operations communities. The Science Meeting provides a forum to review research progress, set CIROH's research agenda, stimulate operations-guided research, review research progress, catalyze collaboration, and discuss pressing national and global issues related to water prediction. The meeting also features numerous networking activities and tours of the National Water Center.

CIROH Sponsors a Think Tank on Building Hydrologic Models from Modules

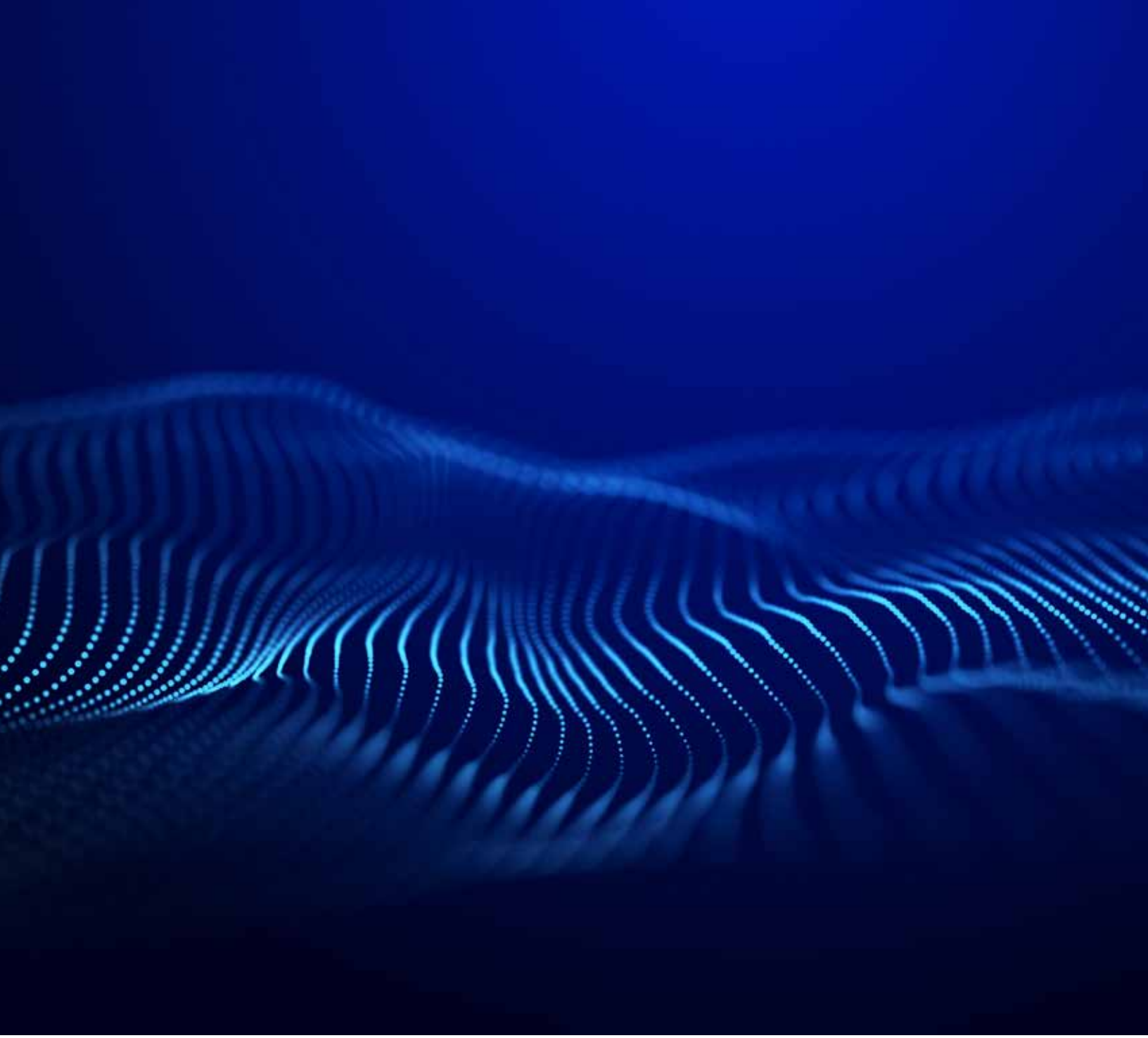
The goal of CIROH's first think tank was to gather a group of the world's experts in large-scale hydrologic modeling and initiate high-level discussions to initiate CIROH's advancement of community water modeling. The think tank organizers hosted a workshop to define protocols for implementing the basic model interface standard to increase the utility of the NextGen framework for water resources modeling problems. The participants in the think tank also helped to advance protocols for CIROH's governance of a community version of the NextGen framework.

CIROH Hosts Networking Event at the American Geophysical Union Annual Meeting

CIROH researchers made more than 80 technical presentations and organized numerous sessions at the 2023 AGU Annual Meeting. At AGU, we hosted a networking event for more than 150 CIROH researchers, partners, and invited guests to connect and build new collaborations. The successful networking event helped establish what will be an annual event at AGU going forward.

Inaugural CIROH Developers Conference a Resounding Success

CIROH hosted its first Developers Conference (DevCon) at the University of Utah in Salt Lake City. The event attracted over 200 registrants and featured a diverse array of presentations, hands-on workshops, and interactive training sessions helping support the development of researchers and operational professionals. By establishing the annual DevCon, CIROH aims to build a strong community of practice that benefits both the consortium and its practitioner partners.



CIROH
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