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CIROH

Global Resilience Institute
at Northeastern University

Building Trust Around Predictive Hydrologic Resources

Case Location: State of Minnesota

June 2024

Funding for this project was provided by the National Oceanic and Atmospheric Administration (NOAA), awarded to the Cooperative Institute for Research on Hydrology (CIROH) through the NOAA Cooperative Agreement with The University of Alabama, NA22NWS4320003.

Introduction

NOAA's National Water Model (NWM), is an innovative tool that can support efforts to enhance community resilience against water-related hazards. A collaborative effort between state agencies and researchers at the University of Minnesota is exploring how the Model's capacity to predict streamflow and inundation can benefit communities situated in flood-prone areas which currently lack ample water data. By combining historical simulations based on retrospective data and current forecasting capabilities, the NWM is being evaluated not only as a predictive tool for water modeling, but also as a resource to assist in community education and emergency planning in Minnesota.

The Challenge

In Minnesota, the "Land of 10,000 Lakes'', water is central to the state's identity. Minnesota's water-rich environment can present unique challenges, especially for rural communities that face significant exposure to flooding. Historically, these communities have often struggled with a lack of critical data which can guide them in planning effective flood response and mitigation measures. Even when reliable flood inundation and mapping data is available, it is often difficult to locate, access, and incorporate into proactive flood risk management strategies. Recognizing these challenges, stakeholders in Minnesota have shown interest in employing the NWM to create visualizations of past flood events, particularly in regions lacking stream gauges or other essential flood monitoring capabilities. Stakeholders recognized that the NWM could provide a historical look-back for known flood events where concrete data is unavailable, thereby providing the means to build interest and momentum at the community level in undertaking flood hazard mitigation measures.

The Value

This use case is most beneficial for stakeholders involved in disaster response and hazard mitigation planning who are looking to enhance their ability to make informed decisions during flood-related emergencies. Incorporating the NWM into resilience planning requires a multidisciplinary team, including GIS specialists, local hydrologists, modelers, and community leaders. These experts can help to interpret the model's outputs in supporting the specific needs of Minnesota's communities and ensure the data's practical effectiveness. This case study may also appeal to a broader audience, including policymakers, academic researchers, and emergency management teams from other states. Members of these groups may find valuable insights on the model's adaptability and effectiveness across different settings.

This case considers Minnesota's varied topographical and climatological features, which significantly impact flood dynamics. In particular, flood modeling approaches tend to struggle with the flat topography in much of the state. It highlights how the NWM addresses some of the challenges presented by both urban and rural environments, such as the lack of timely information during flood events and the scarcity of historical data to assess probabilistic flood risk. This approach looks to the potential of the NWM as both a facilitator of broader community engagement and inter-agency collaboration, paving the way for enhanced statewide flood mitigation strategies.

Partner Community Overview

This use case was developed in collaboration with U-Spatial, the University of Minnesota's geospatial information center. U-Spatial supports geospatial research throughout the state's university system and has worked alongside the Minnesota Department of Transportation (MN DOT), including on shared advisory work. U-Spatial and MN DOT share a common interest in developing a more robust geospatial information infrastructure in the state. U-Spatial has also worked with county governments to close the water data gap by lending their expertise in developing tools that make water-related information easier for local leaders in rural communities with limited information and staffing capacity to access and interpret. Under this program, U-Spatial has partnered with 19 rural counties in Minnesota to support the development of state-mandated hazard mitigation plans.

MN DOT is impacted by many of the same data gaps that create challenges for the state's rural communities. The department has sought to improve its flood monitoring and prediction capabilities wherever possible in order to improve its ability to anticipate and respond to flood events with the potential to disrupt infrastructure across the state.

Case Characteristics and Features

The first stage of the use case showcased how streamflow data from NOAA's NWM retrospective data can generate experimental, flood extent visualizations for known historical floods within a region of interest. The NWM retrospective data consists of model simulations that offer historical context to current near real-time streamflow, soil moisture, and snowpack conditions. Version 3.0 covers a period of 44 years (1979-2023) and is publicly accessible. FIM is a flood inundation mapping method based on terrain data that is publicly available; it creates Height Above Nearest Drainage (HAND) maps and synthetic rating curves using topographical datasets, which are then utilized with streamflow data to generate flood maps.

To enable this use, researchers from the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) prepared code allowing users to identify the nearest stream reach code to a given set of geographic coordinates. Accompanying instructions guide users through the process of accessing retrospective streamflow estimates for the specified stream reach. Once peak flow values from historical events have been identified, users can then generate flood extent maps from these historical estimates using a workflow available through GitHub. The workflow converts flow values into flow depth (stage) using synthetic rating curves, then delineates inundation by comparing stage values with the HAND values. Essentially, if the HAND value of a location is lower than the stage, the location is designated as flooded. While this process currently requires some amount of technical expertise, work is underway to simplify and potentially automate this process. The aim is to reduce the technical burden and enhance the user experience for stakeholders. Ideally, stakeholders will be in a position to focus on the utility of this information, rather than being overwhelmed by the hydrologic techniques at work. However, users will still need to be able to follow instructions outlined in a Jupyter notebook and have a working knowledge of GIS software.

While Minnesota stakeholders were impressed by the ability to generate inundation maps from NWM retrospective flow values, and were able to replicate the workflow demonstrated by CUAHSI by following instructions in a Jupyter Notebook, they did not feel comfortable operationalizing these outputs without first ground-truthing them in a local context. The accuracy of the HAND mapping methodology can be easily understood by comparing maps generated this way with maps of observed historical events corresponding to a known flow value. However, an important challenge stakeholders in Minnesota identified was the need to develop trust in a source of data when there are no other sources of data to corroborate the information provided by the inundation maps.

Tool Comparisons and Limitations

The inundation maps derived from NWM retrospective flow estimates allow users to visualize estimated maximum inundation extents along a given reach, as well as depth estimates. Depth estimates are currently not calibrated for confident interpretation, but efforts are underway to further improve them. A series of modeled inundation maps corresponding to peaks in estimated flow allows users to generate flood maps for a specific region, displaying the likelihood of flooding occurrences in known problem spots. Since the retrospective flow values being used to generate FIMs in such cases would be modeled, rather than observed, this application may be particularly useful as a way of corroborating events that were attested or observed, but for which little useful data exists.

Stakeholders from MNDOT currently rely on a variety of resources, including USGS StreamStats, FEMA maps, and survey/photographic resources where available, while U-Spatial's current hazard assessment workflow combines a hydrologic and hydraulic (H&H) modeling approach with a HAZUS-based tool to estimate damages during a 100-year flood for locations where alternatives, like FEMA regulatory maps, are not available. While they noted that this approach has known inaccuracies, they stated that they would like to verify that the information derived from a NWM-based approach to determining the 100-year flood risk is at least as reliable as currently available tools before operationalizing it.

In addition to inundation maps generated by users through this process, the National Water Center is collaborating with NOAA's River Forecast Centers to roll out predictive FIMs for the entire continental United States. These maps are not yet available for Minnesota as of 2024 but will be in the future. Crucially, these maps are not a replacement for USGS floodplain maps or FEMA's flood insurance rate maps (FIRMs). The National Water Model is an evolving service; its FIM capabilities are currently largely experimental, and its predictions hold no regulatory authority. While maps generated through this process may help communities to identify areas of interest for long-term resilience planning, they should be understood as estimates and used to guide, rather than determine, final decision-making.

Lessons for Communities

Users in a position similar to U-Spatial must not only understand the National Water Model, its capabilities, and its limitations, but also be able and prepared to navigate and communicate uncertainty. In some use cases, existing materials may offer such guidance.

1. *Identify the Trust Threshold:* All hydrologic resources that don't rely on observed flow data include some degree of speculation and uncertainty. Throughout the process, the matter of trust in the National Water Model and its outputs was central to its usefulness and usability. The Minnesota use case stakeholders were able to identify a pathway by which they will continue to build trust with the NWM, so new users of the NWMI should anticipate establishing their own pathways to develop trust as well.

2. *Compare Multiple Information Sources:* Once the threshold of trust is understood, it is easier to develop a plan to evaluate trust in a particular tool. By understanding how predictions from trusted resources are calculated, users can evaluate how the NWM may be similar or different in their local context. At the most basic level, users can monitor NWM predictions ahead of predicted storms and compare those predictions with observed outcomes in highly impacted locations. The NWPS interface makes it easy to flag high-risk locations ahead of weather events for later comparison with real-world outcomes.

3. *Remain Flexible, but Recognize Limitations*: The National Water Model is an evolving resource, and although it is versatile, it may not be the ideal tool for every end goal. Its effectiveness can vary by region, which may limit its precision for local decision-making or specific water management objectives. Recognizing these limitations, stakeholders should look for opportunities to supplement existing tools or use the NWM in conjunction with other data sources and local insights. By doing so, they can harness its strengths for enhanced planning and execution, contributing to the continued evolution of the NWM and its capabilities for localized application.

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