Rethinking model reliability: A dual evaluation of the National Water Model using time series and extreme events

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NATIONAL HYDROLOGIC WARNING COUNCIL

CIROH
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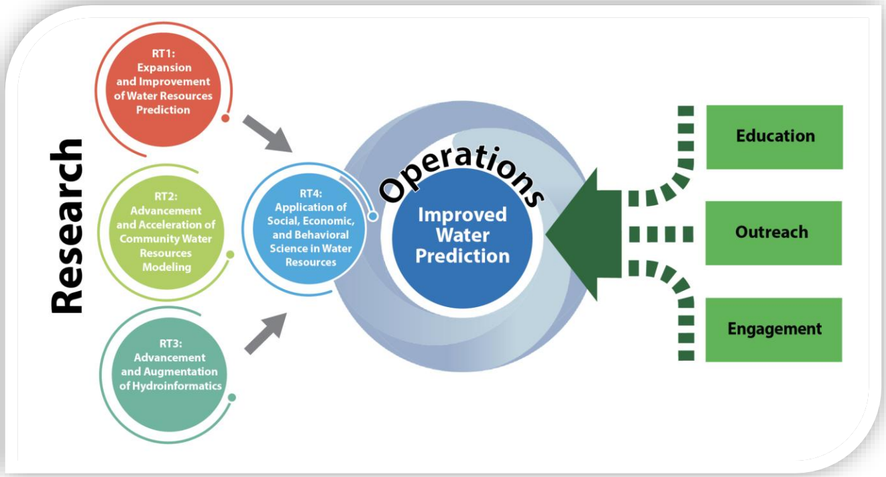
Introduction

- Extreme flood and drought predictions
  - Critical for water resource management and hazard mitigation
  - Traditional model evaluation often relies on long-term time series metrics – may overlook critical performance during extreme events
  - Event-based evaluation focuses on extreme flood and drought events
- We present a twofold evaluation of the National Water Model (NWM) version 3.0 by conducting the both
  - Traditional model evaluation approach
  - Event-based model evaluation approach

Cooperative Institute for Research to Operations in Hydrology (CIROH)

- Addressing flood / drought prediction challenges
- Advancing the Next Generation Water Resources Modeling Framework (NextGen)
- Accelerating research into operational hydrologic forecasting across the United States and its Territories

ciroh.ua.edu



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OWP OFFICE OF WATER PREDICTION

NOAA

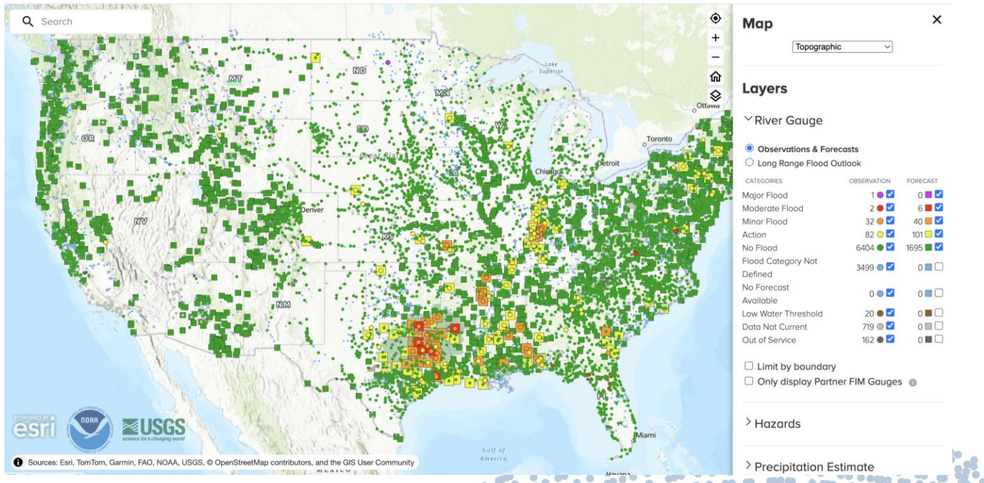
NWC NATIONAL WATER CENTER

NWM and NextGen Framework

CIROH DocuHub

NextGen GitHub Repo

- NWM provides operational forecast streamflow guidance for currently underserved locations up to 3.4 million river miles
- NextGen is a continental-scale model-agnostic water resources modeling framework (flexible, consistent, interoperable)
- Generates high-resolution, spatially continuous estimates of major water cycle components
- Diverse model formulations (Conceptual, ML), open-source development (GitHub, unit testing, etc.), and friendly to domain scientists and engineers



RESEARCH ARTICLE

JAWRA

NOAA's National Water Model: Advancing operational hydrology through continental-scale modeling

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Abstract

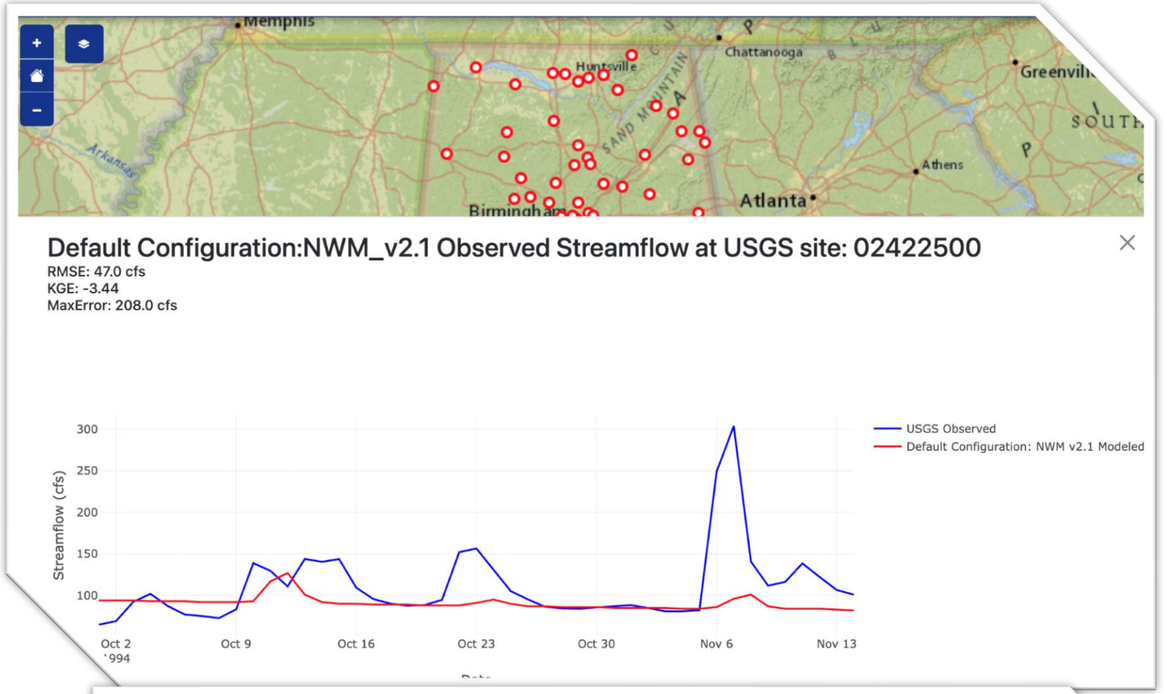
The National Weather Service (NWS) Office of Water Prediction (OWP), in conjunction with the National Center for Atmospheric Research and the NWS National Centers for Environmental Prediction (NCEP) implemented version 2.1 of the National Water Model (NWM) into operations in April of 2021. As with the initial version implemented in 2016, NWM v2.1 is an hourly cycling analysis and forecast system that provides streamflow guidance for millions of river reaches and other hydrologic information on high-resolution grids. The NWM provides complementary hydrologic guidance at current NWS river forecast locations and significantly expands guidance coverage and water budget information in underserved locations. It produces a full range of hydrologic fields, which can be leveraged by a broad cross section of stakeholders ranging from the emergency responder and water resource communities, to transportation, energy, recreation and agriculture interests, to other water-oriented applications in the government, academic and private sectors. Version 2.1 of the NWM represents the fifth major version upgrade and more than doubles simulation skill with respect to hourly streamflow correlation, Nash Sutcliffe Efficiency, and bias

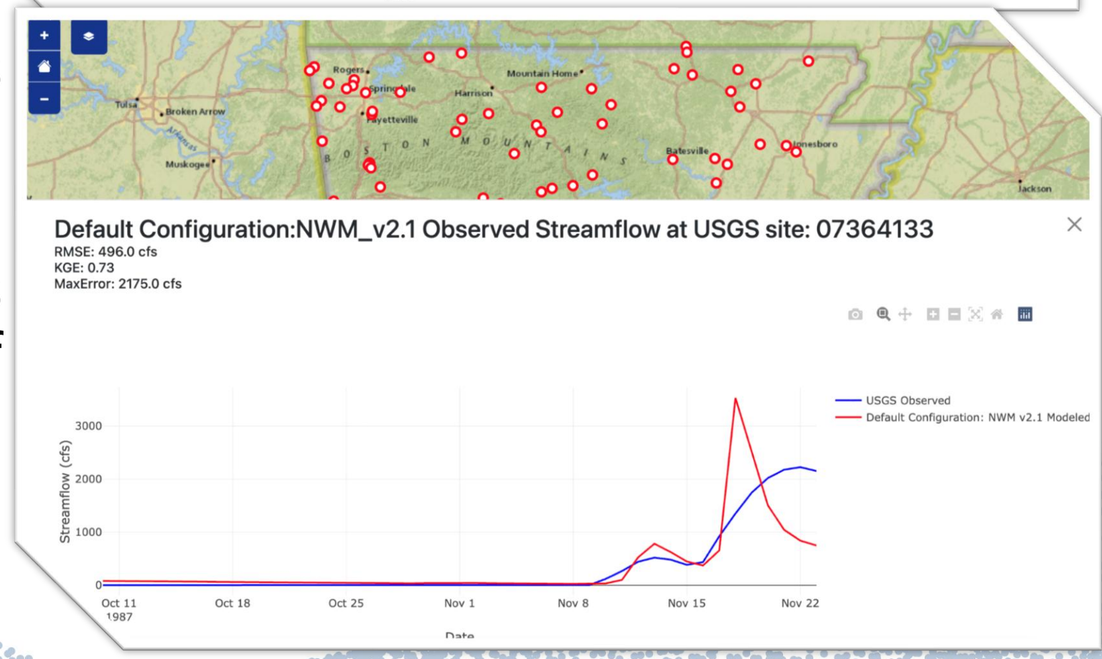
Study Objectives

Goal: Investigate NWM's reliability in predicting extreme events

Objectives:

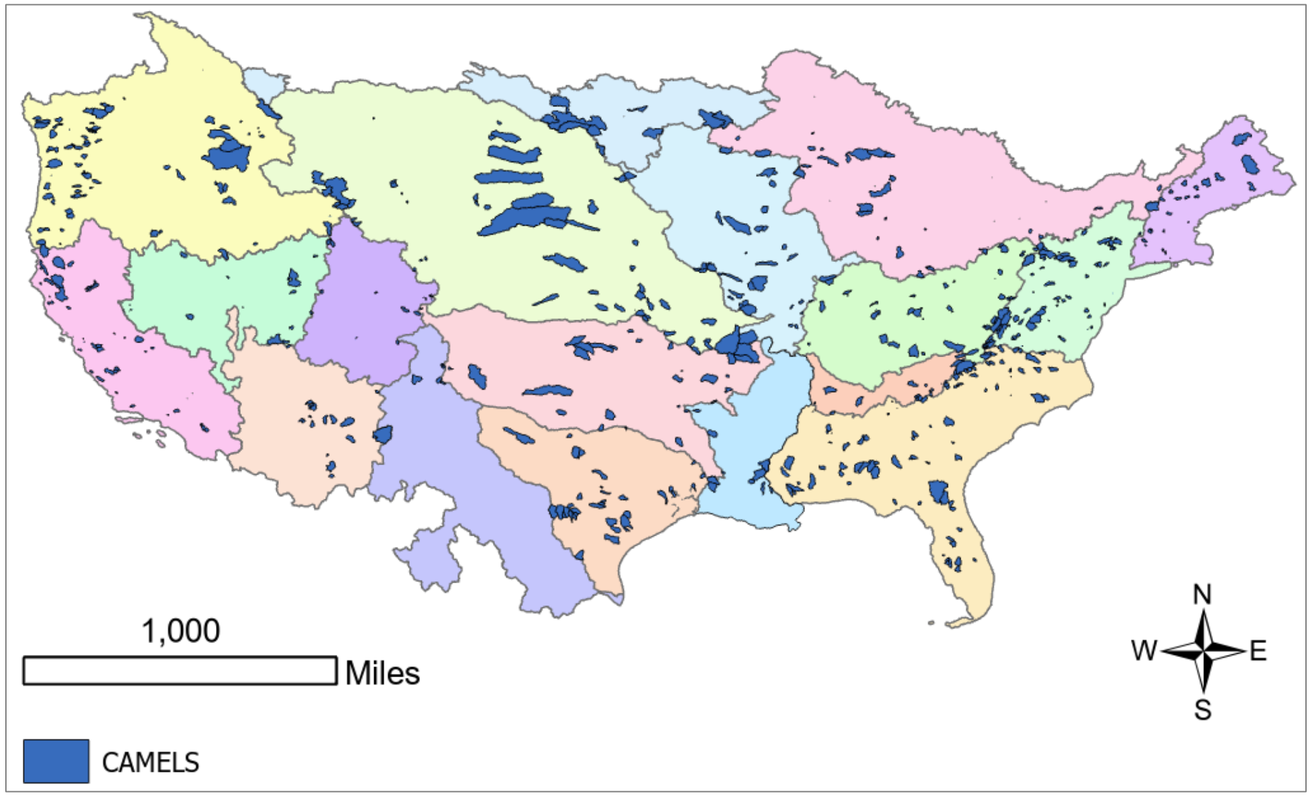
- Compute model performance metrics based on conventional time series analysis
- Compute model performance metrics based on flood and drought events of different return intervals



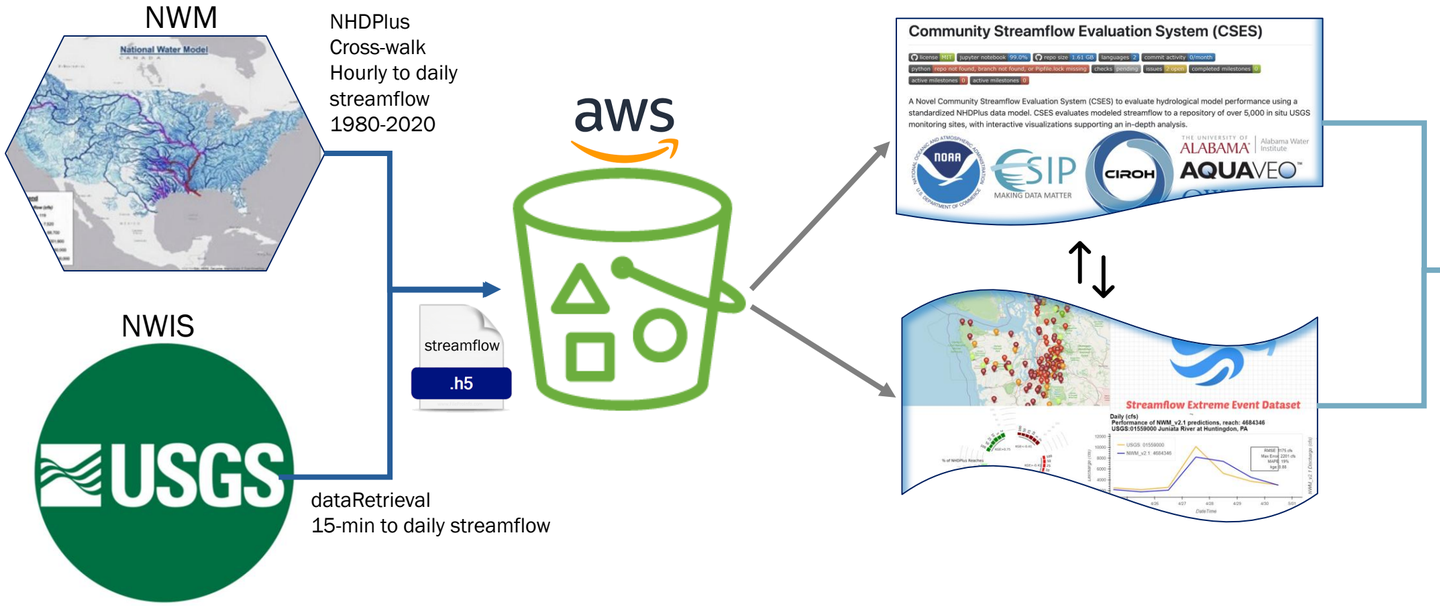


CAMELS Basins

- **How many basins?**
  - ✓ 671
  - ✓ We selected 634 that have streamflow data for both USGS and NWM
- **Size of the basins**
  - ✓ 4 to 25000 (approx.) sq. Km
- **Basin attributes**
  - ✓ Climate, Topography, Hydrologic Signatures, Soil, Vegetation, and Geology
- Why CAMELS basins?
  - ✓ Minimal human impacted – headwater basins
  - ✓ Included in the NWM calibration
  - ✓ Standard dataset



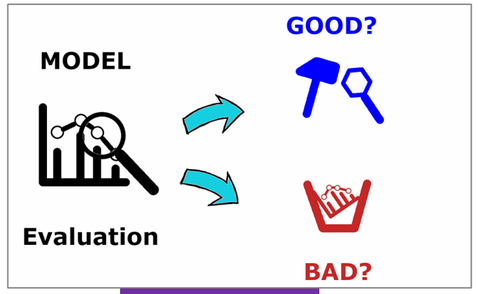
Methodology for model evaluation



CAMELS Dataset (Addor et al., 2017)

Total 671 Basins

634 Basins selected



NWM v3.0

Long time-series

Extreme events

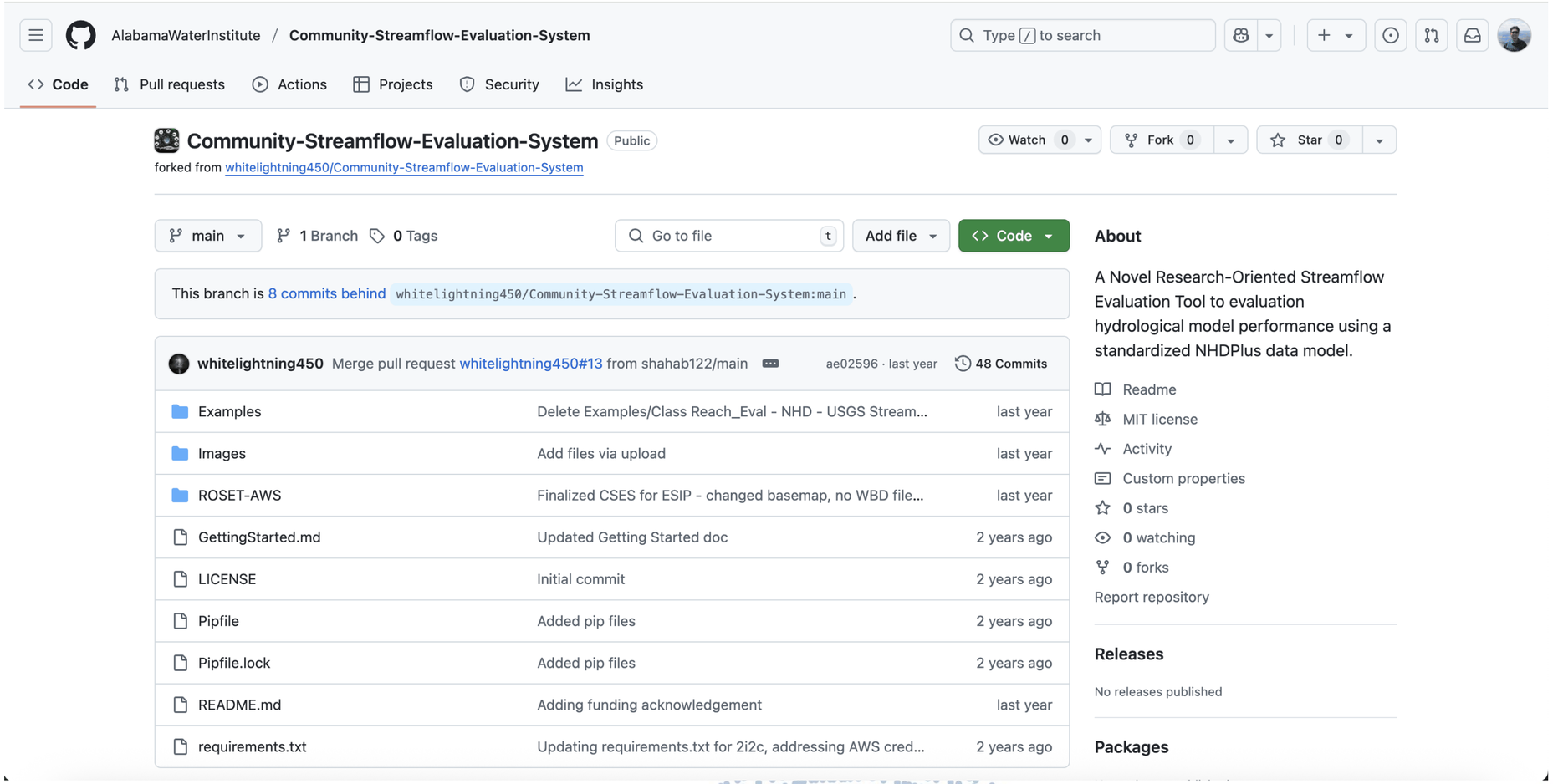
Flood: f(Annual Maximum Flow, T)
Drought: f(Annual Minimum Flow, T)

CIROH DocuHub

CSES GitHub

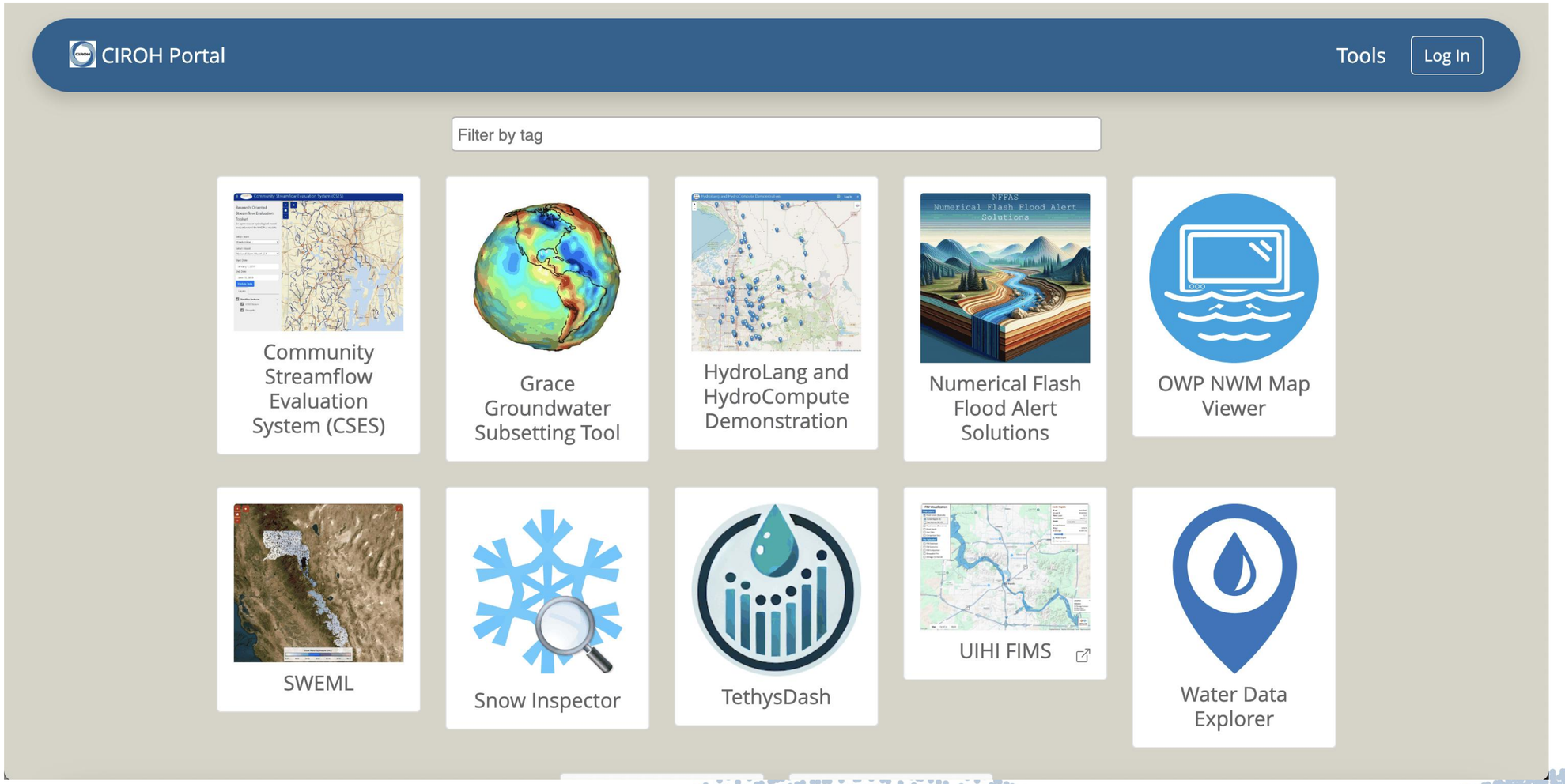
SEED-CSES GitHub

NWM evaluation using Python Tool



CSES GitHub

NWM evaluation using Tethys Tool

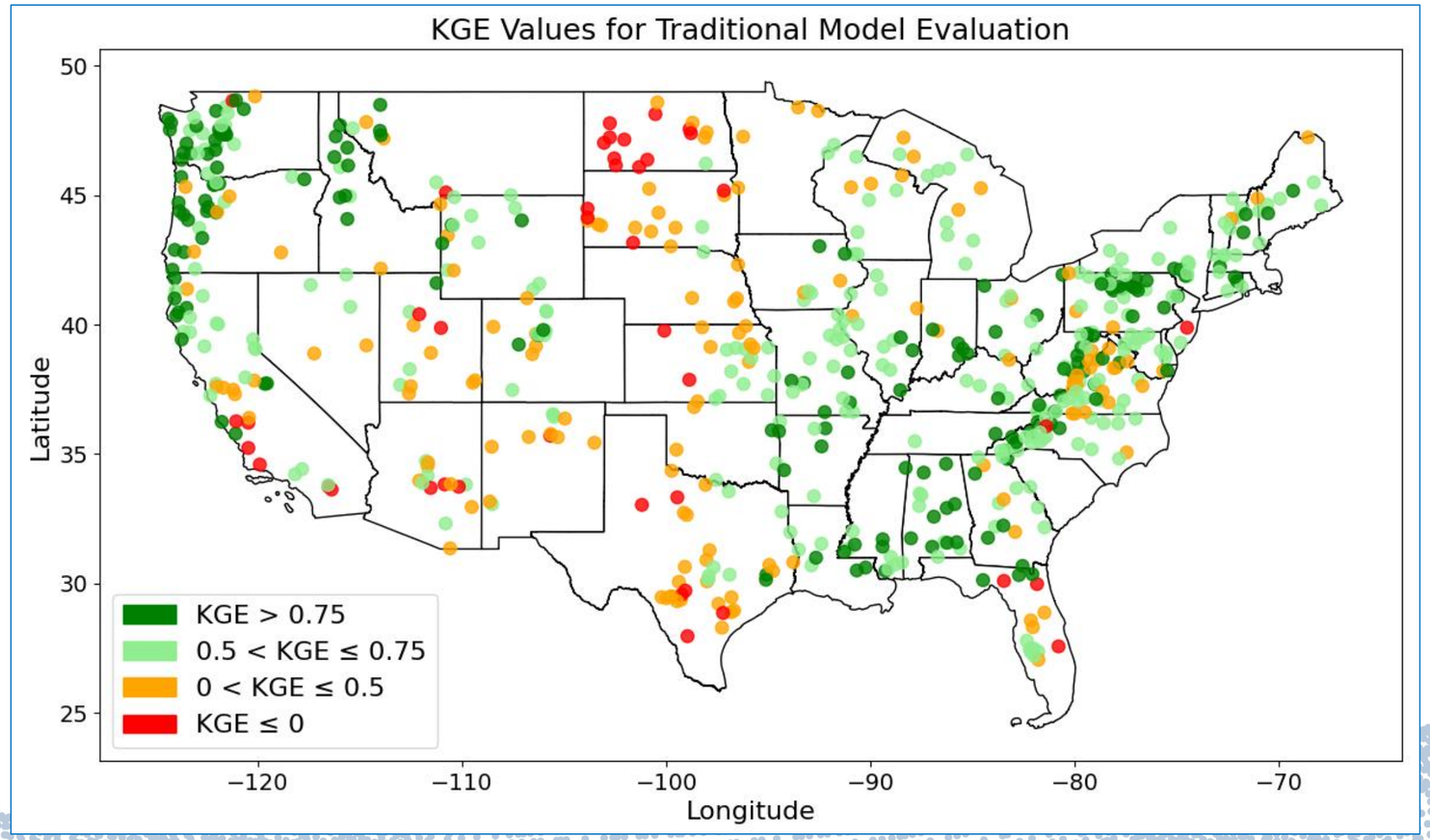


Tethys-CSES App

Results

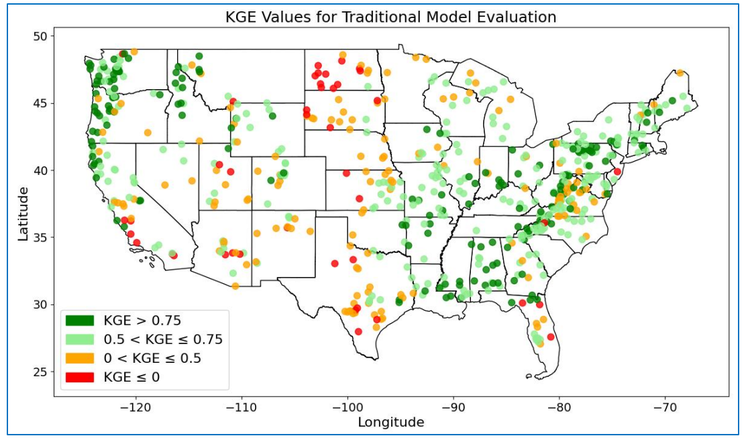
Model Performance – Traditional Approach

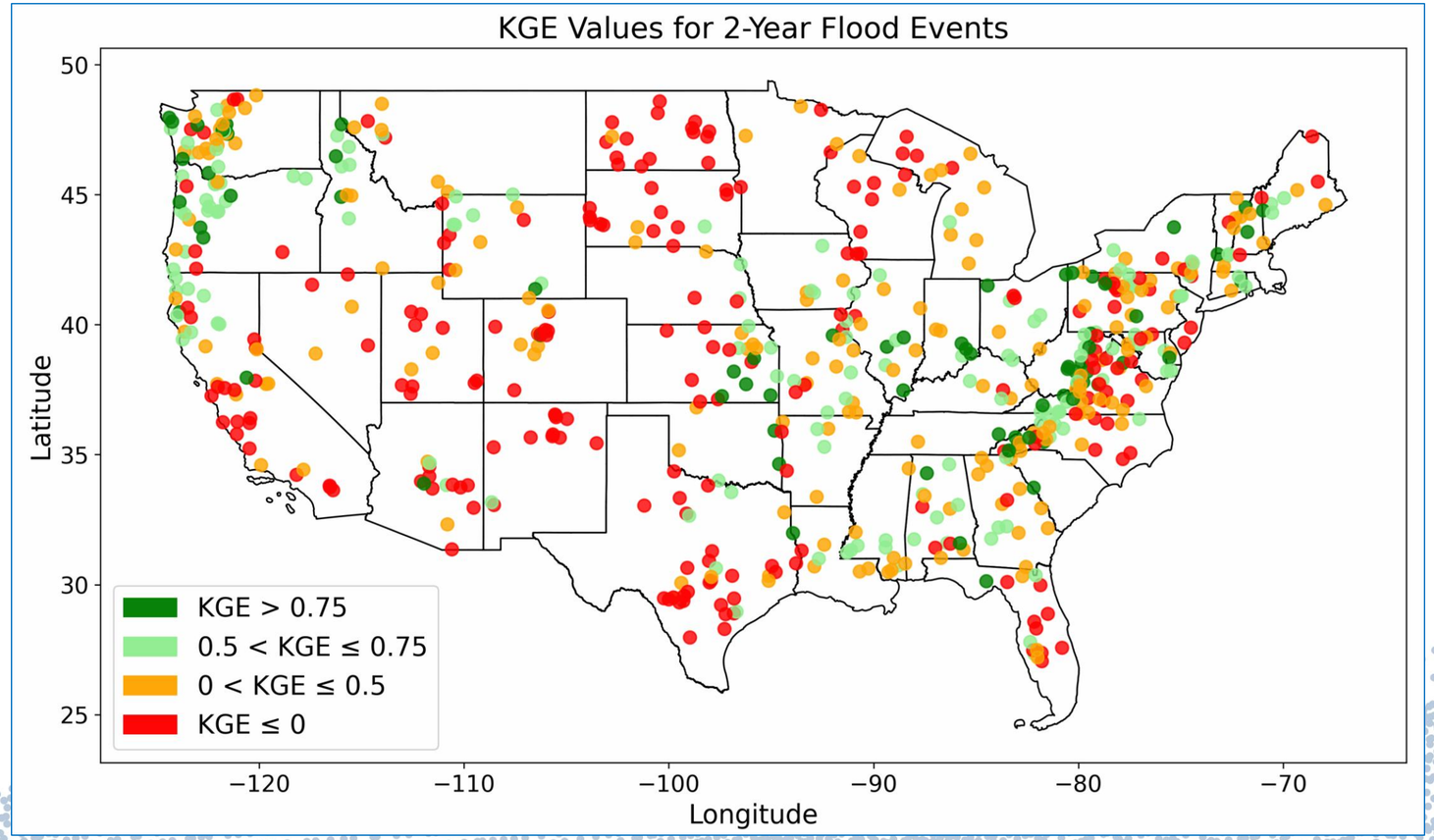
- In general, NWM 3.0 performs better in the east and northwest regions
- Central US, Arid/semi-arid, and coastal regions may need more attention



Model Performance – Flood Events

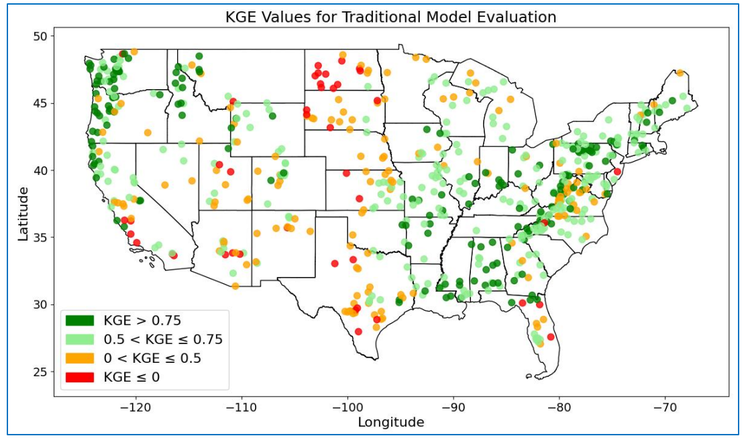
- CAMELS basins in the northwest and eastern regions show better performance
- Minor difference in the performance between the return intervals

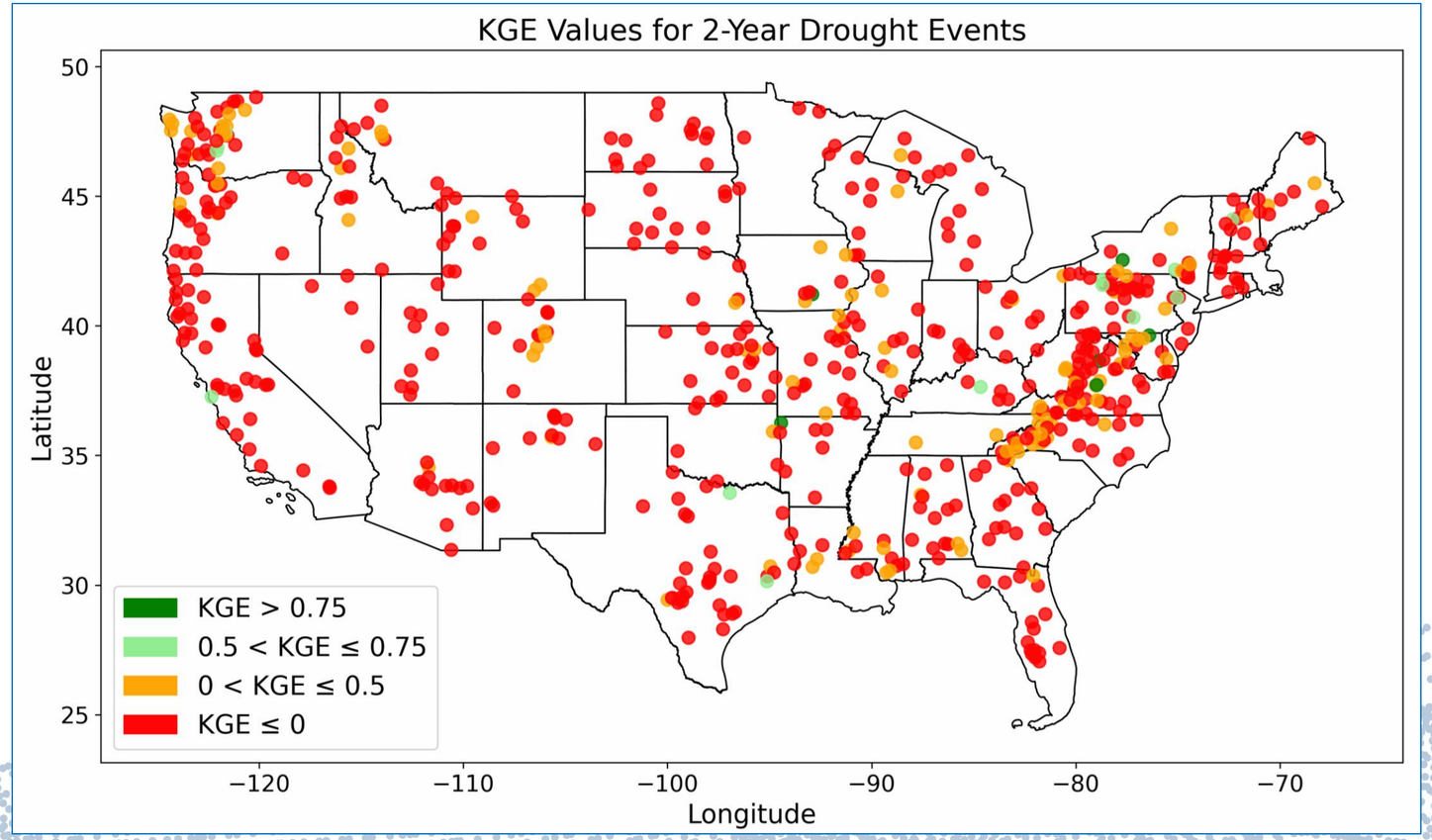




Model Performance – Drought Events

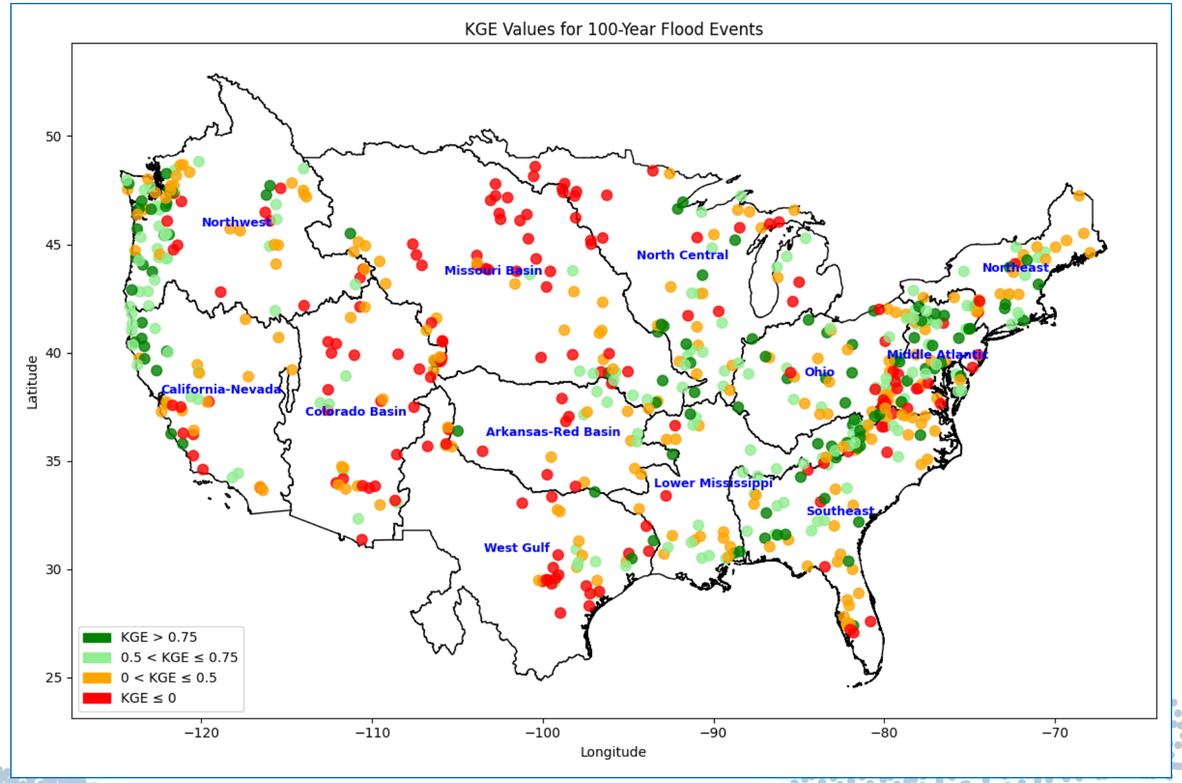
- Overall, NWM 3.0 fails to simulate the extreme drought events
- NWM 3.0 performs better in simulating flood than the drought events

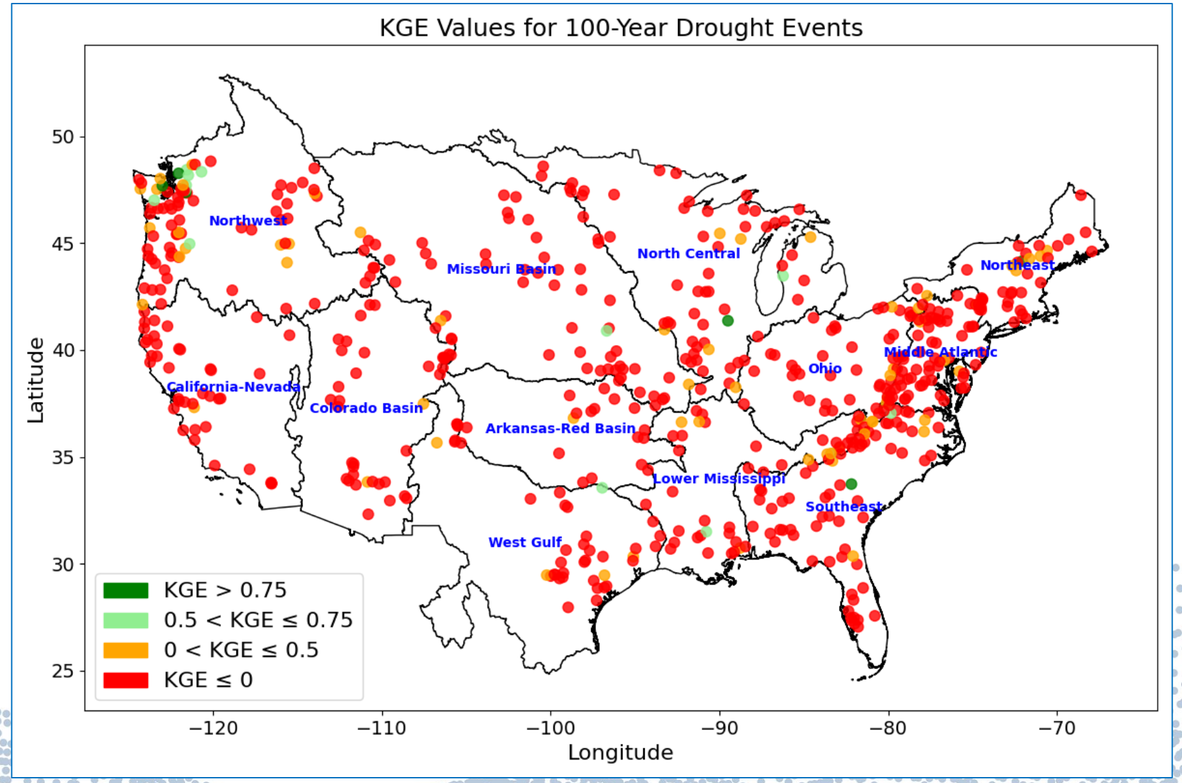




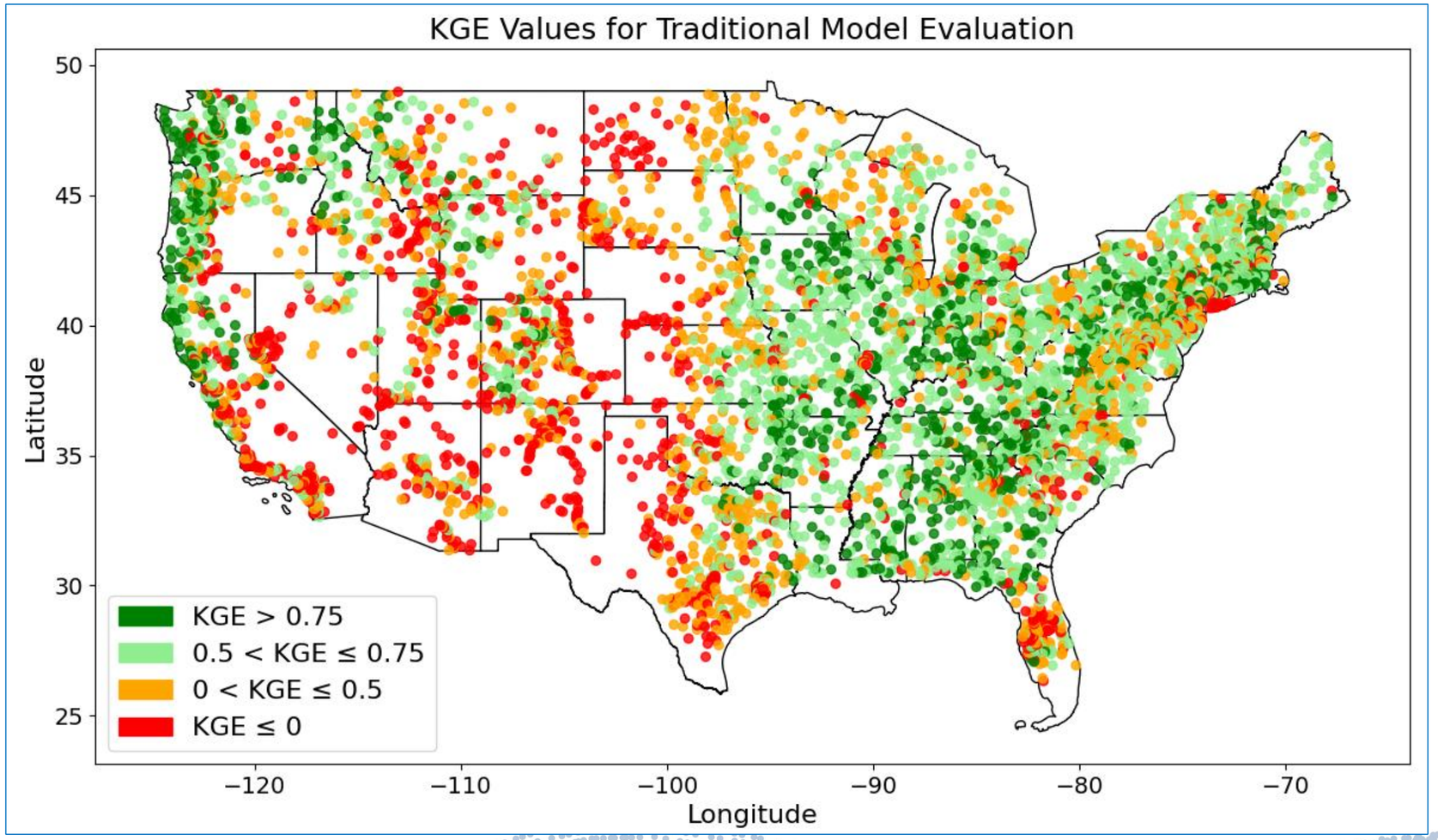
Performance in the RFC Regions

- Some RFCs may issue warning more reliably than others
- Lower Mississippi, North Central, Northeast, and Northwest

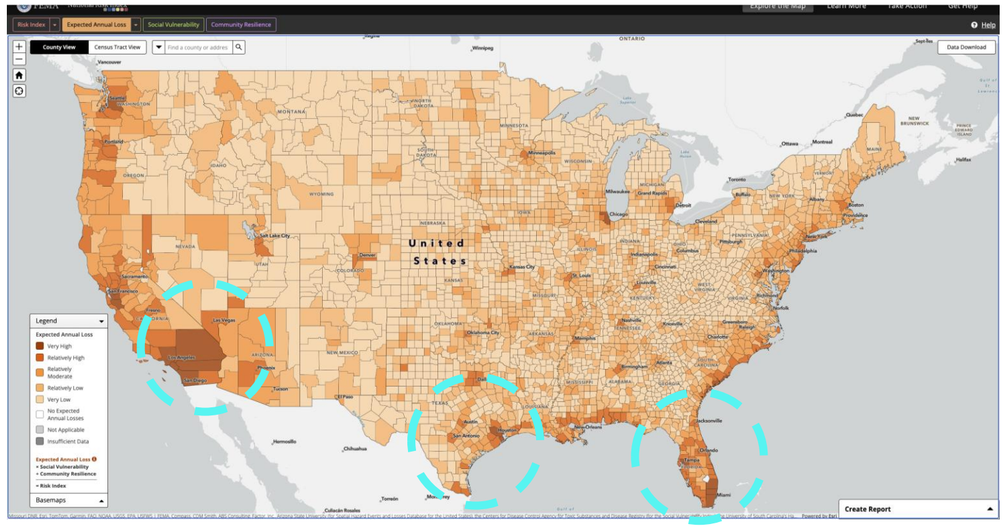


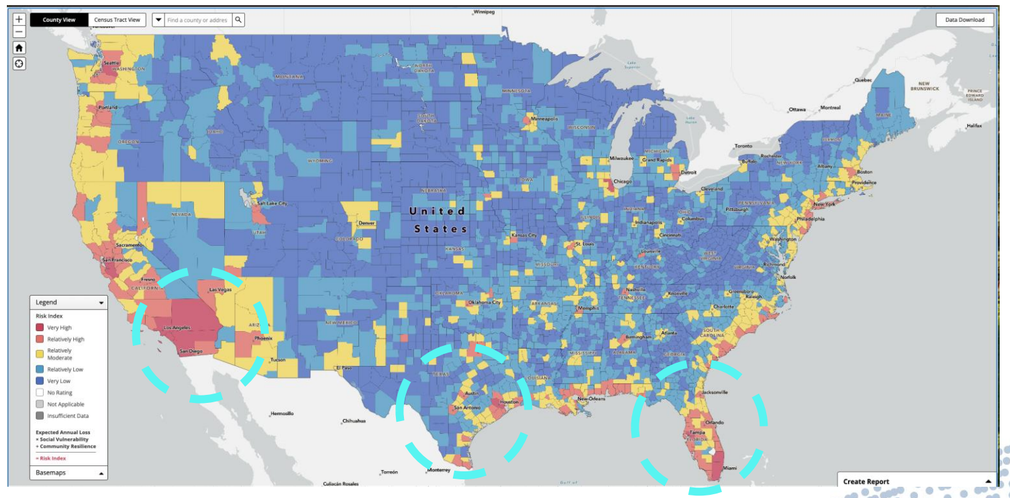


More Capability of Our Tool – Entire CONUS

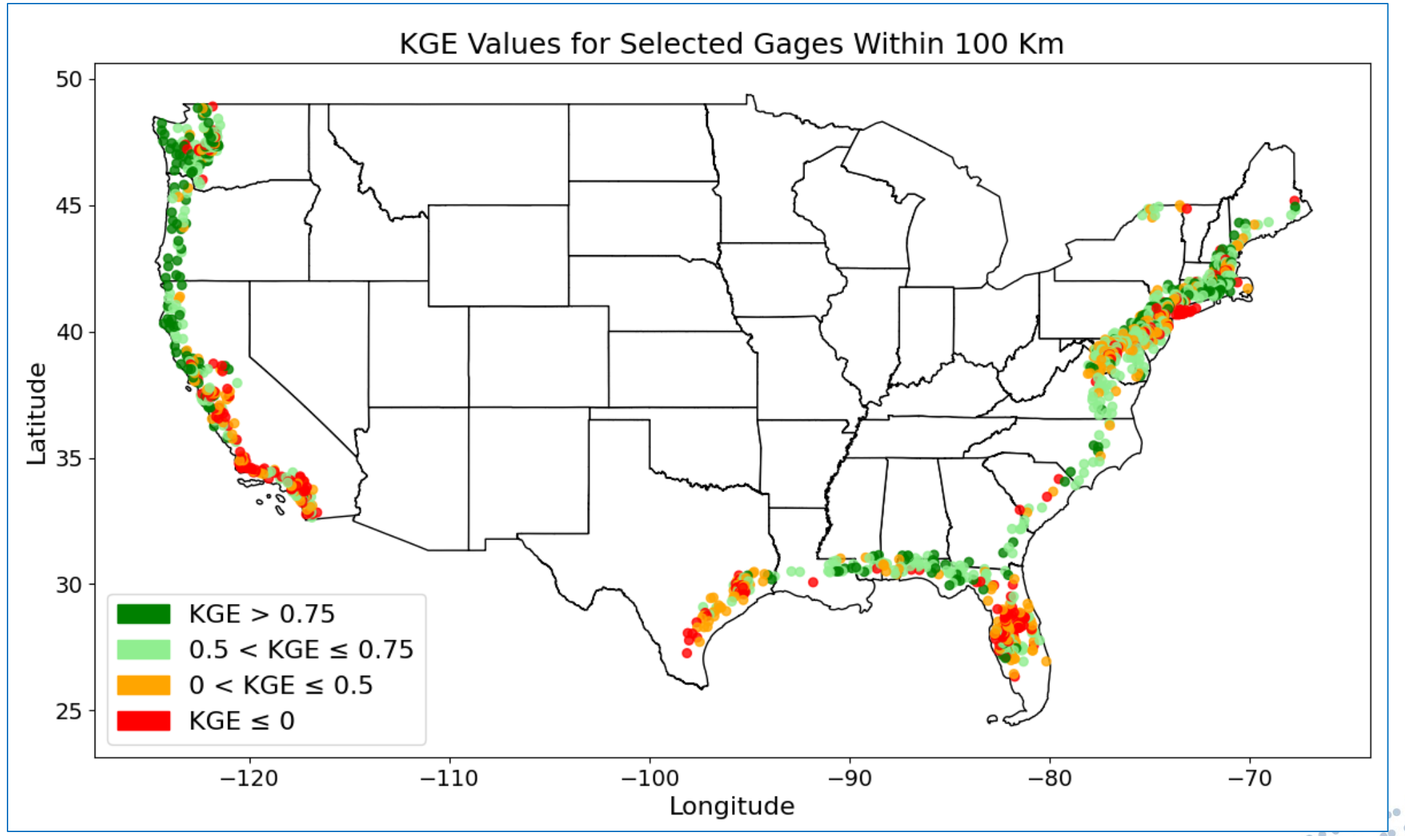


Model Performance vs Annual Loss/Risks





Source: https://hazards.fema.gov/



Key Findings and Conclusions

- NWM performance decreases when event-based evaluation is considered as compared to the traditional model evaluation
- The model performs better in simulating floods than droughts
- Some RFCs are in a better position to issue reliable warnings
- Model needs better calibration in the high-risk areas
- Our tools can support RFCs, local government, and water managers in making informed decisions

Next Steps

- Include more hydrological models (e.g., SUMMA, SAC-SMA, TOPMODEL) from NextGen Framework
- Expand to more basins outside CAMELS
- Conduct more frequency analysis (with more probability distribution methods) using the tools
- Include USGS gauges outside CONUS
- Connect to TEEHR for more evaluation metrics and update our Tethys data visualization

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Thank You!

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