Advancing T-route Toward Flexible and Scalable Flow Routing to Support Open Streamflow Data Access

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Abstract

As demands grow for high-resolution, physics-informed streamflow modeling across the continental United States, river routing frameworks must evolve to handle increasing data volumes and diverse hydrofabric structures. We present recent advancements to T-route, a river-routing engine developed by NOAA's Office of Water Prediction (OWP) for the National Water Model that supports hydraulic channel routing (including diffusive-wave), reservoir routing, and streamflow data assimilation. Building on its foundation of efficient, dependency-aware network traversal, we broaden T-route's capabilities across multiple dimensions—improving runtime and space efficiency, incorporating the latest hydrofabrics with a more physically based treatment of catchment outflows, and expanding user-defined configuration options for more control over routing behavior.

These improvements support a broader effort to evaluate T-route's performance across multiple versions of NWM hydrofabrics, including ongoing experiments routing 40 years of continental flow data using both the current NWM hydrofabric and the hydrofabric of Next Generation Water Resources Modeling Framework (NextGen), its successor. Our long-term goal is to leverage these advances to build a community-accessible, continuously updating continental streamflow datastream that supports hydrologic research and decision-making.

Introduction

T-Route

- Dynamic, flexible, and modular channel routing model for vector-based river networks (e.g., NHDPlus HR in NWM, WaterML 2.0 HyFeatures in NextGen).
- Computes streamflow using NWM-provided catchment runoff while strictly enforcing upstream-to-downstream dependency order.

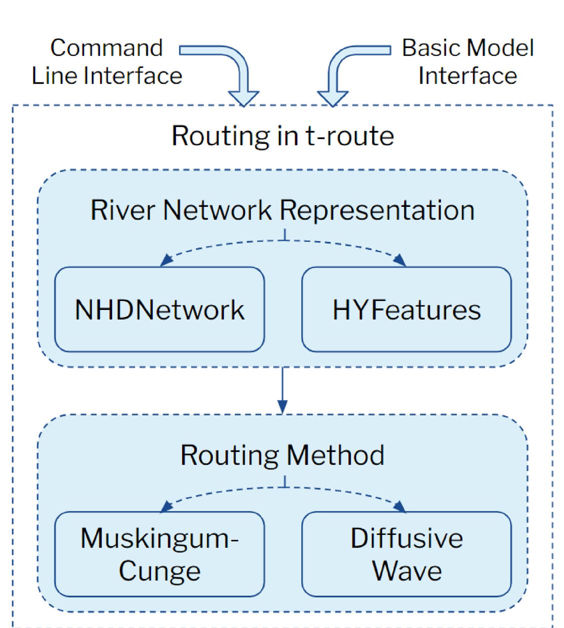

Figure 1. T-route Scheme

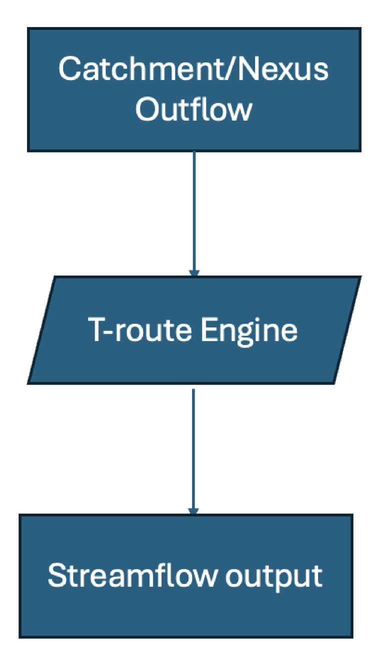

Figure 2. T-route Pipeline

Continental Routing

- The U.S. is divided into 18 independent HUCs, each routed separately in a node.
- Each HUC is further partitioned into smaller subnetworks to increase parallelism.
- The Mississippi basin is the largest and dominates runtime—optimizations here significantly reduce total routing time.

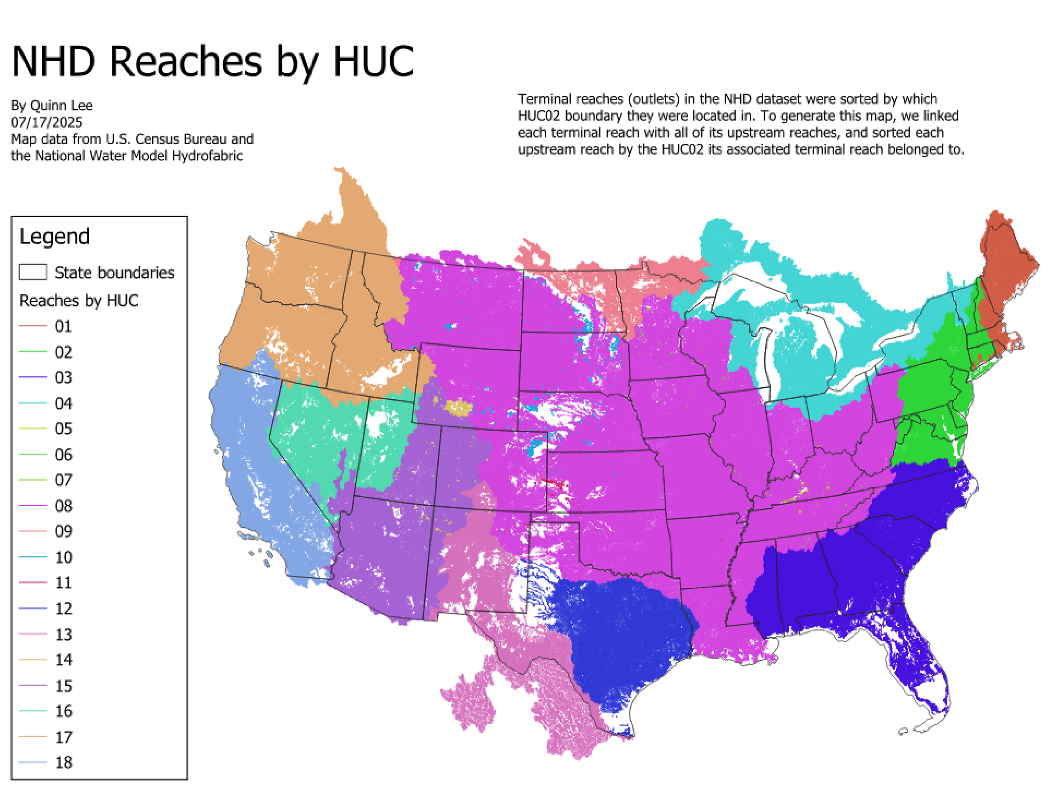

Figure 3. NHD Reaches by HUC

Results

Runtime Optimization

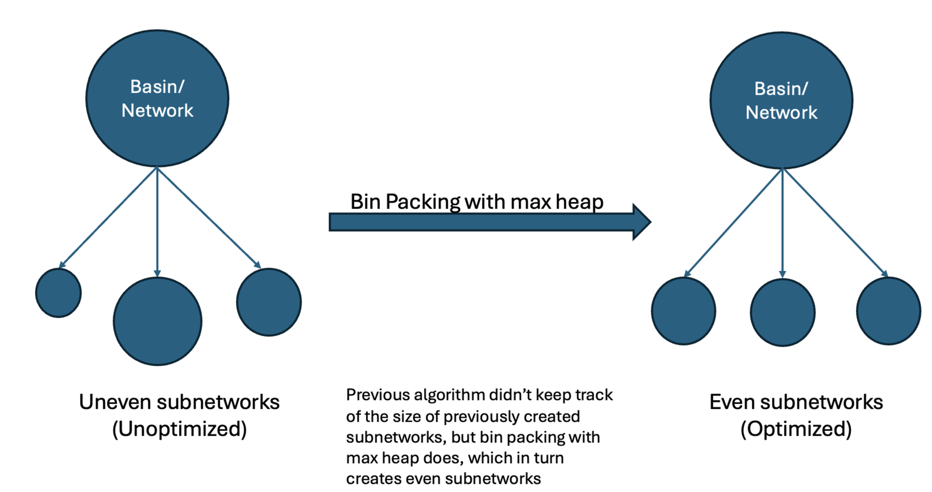

Figure 4. Even Network Distribution Representation [1]

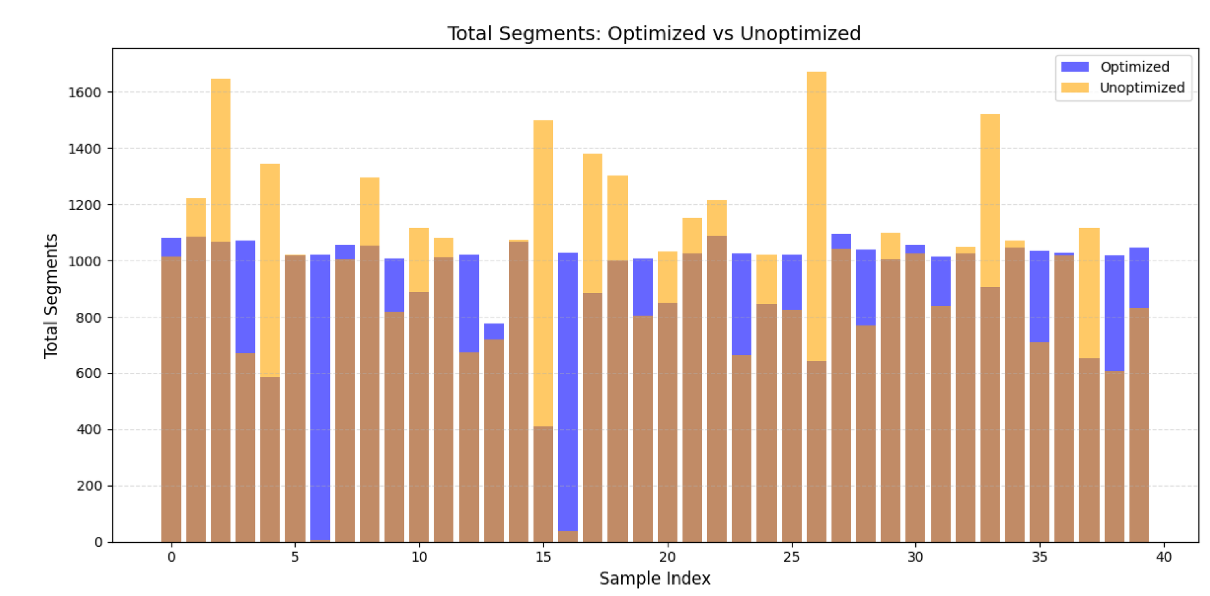

Figure 5. Optimized vs Unoptimized Network Distribution with Target Size 1000

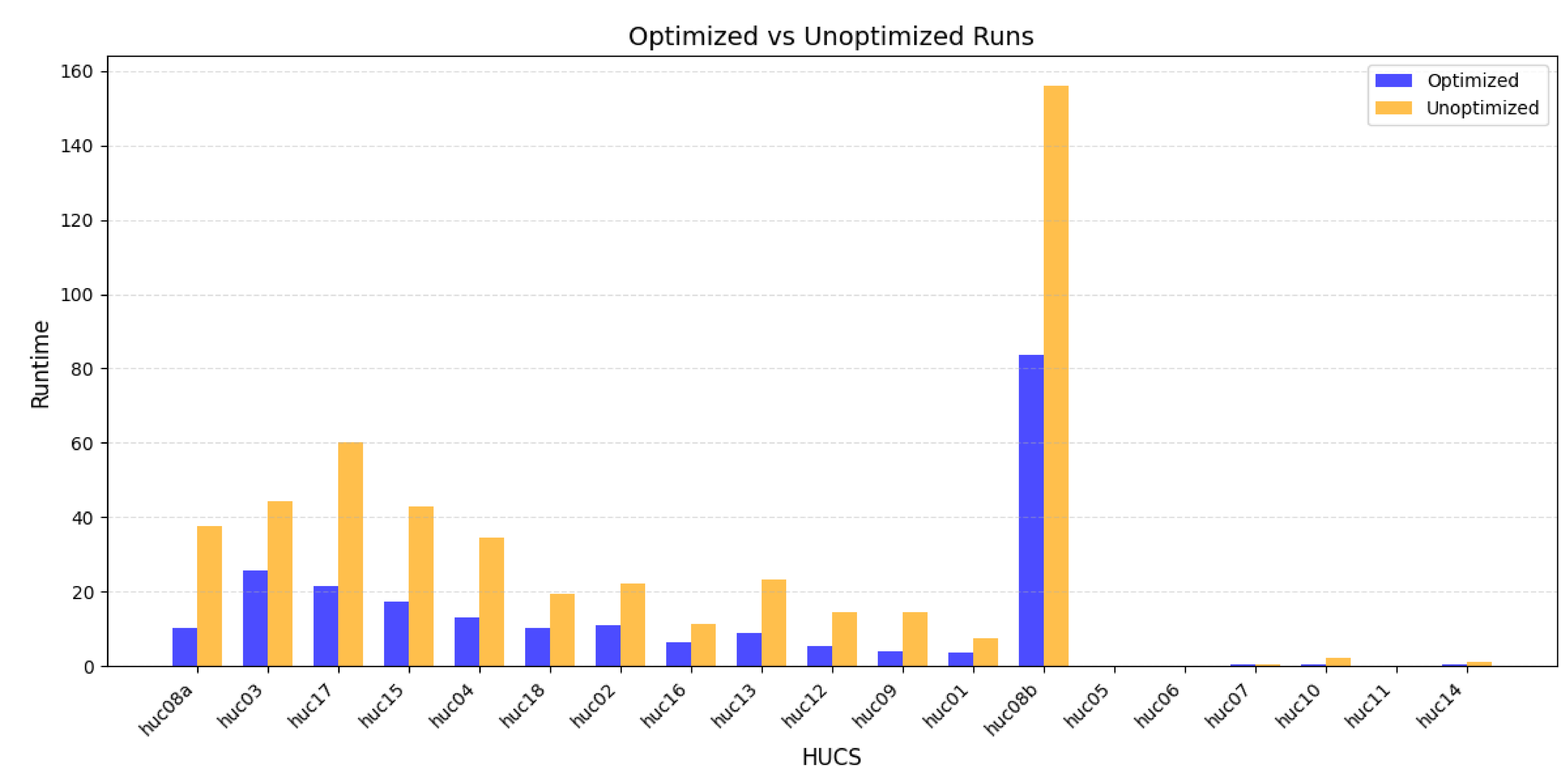

Figure 6. Runtime Across Each HUC (Average Speedup 2x)

Space Optimization

- With internal code refactoring, the memory usage was reduced by approximately 30%.

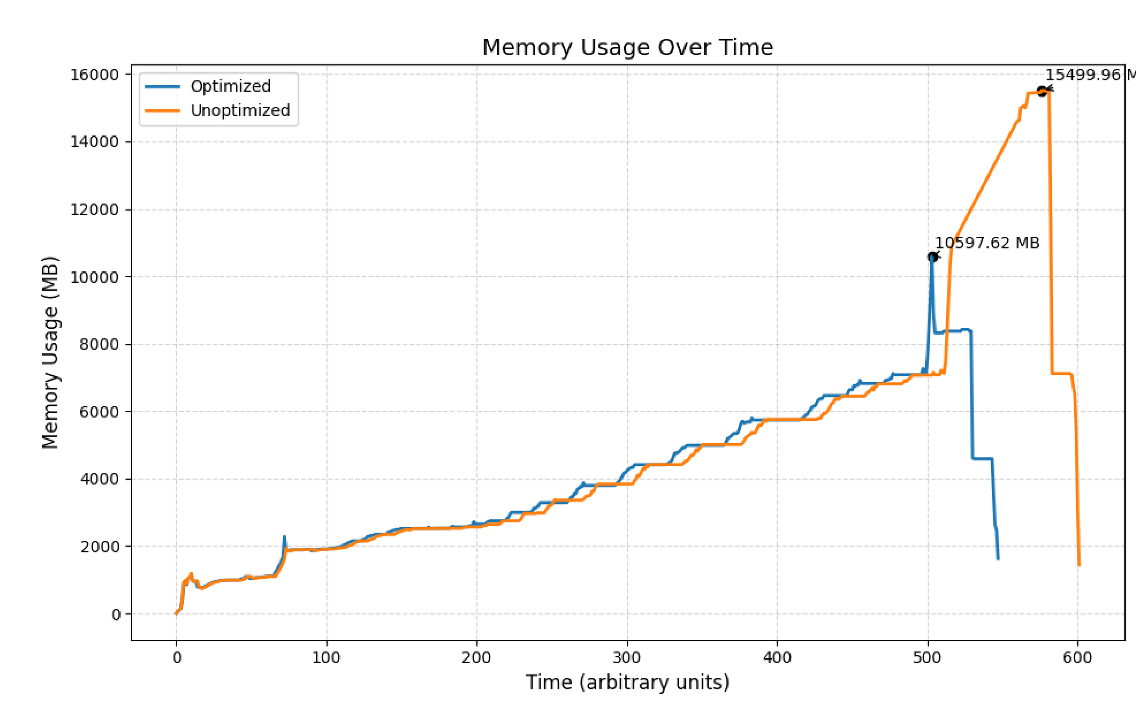

Figure 7. Memory Utilization in Mississipi Run

Expanded Support for Catchment-Based Runoff

- Added support for catchment runoff (previously limited to nexus outflow).
- Enables improved parallel partitioning, contributing to reduced overall runtime.

Configurable GIUH Node Parameter

- Allows users to choose between uniform along-reach runoff distribution or addition of runoff directly at the downstream end.

Significance

These performance improvements—balanced parallel subnetworks and reduced memory usage—significantly expand T-route's ability to handle large-scale routing tasks. These enhancements lower computational cost, make continental routing more efficient, and reduce hardware requirements, enabling more users to run high-resolution routing experiments.

New support for diverse hydrofabrics, catchment-based runoff, and configurable GIUH handling increases T-route's adaptability. These additions strengthen its role as a flexible, interoperable routing engine capable of meeting the needs of next-generation hydrologic modeling.

Future Direction

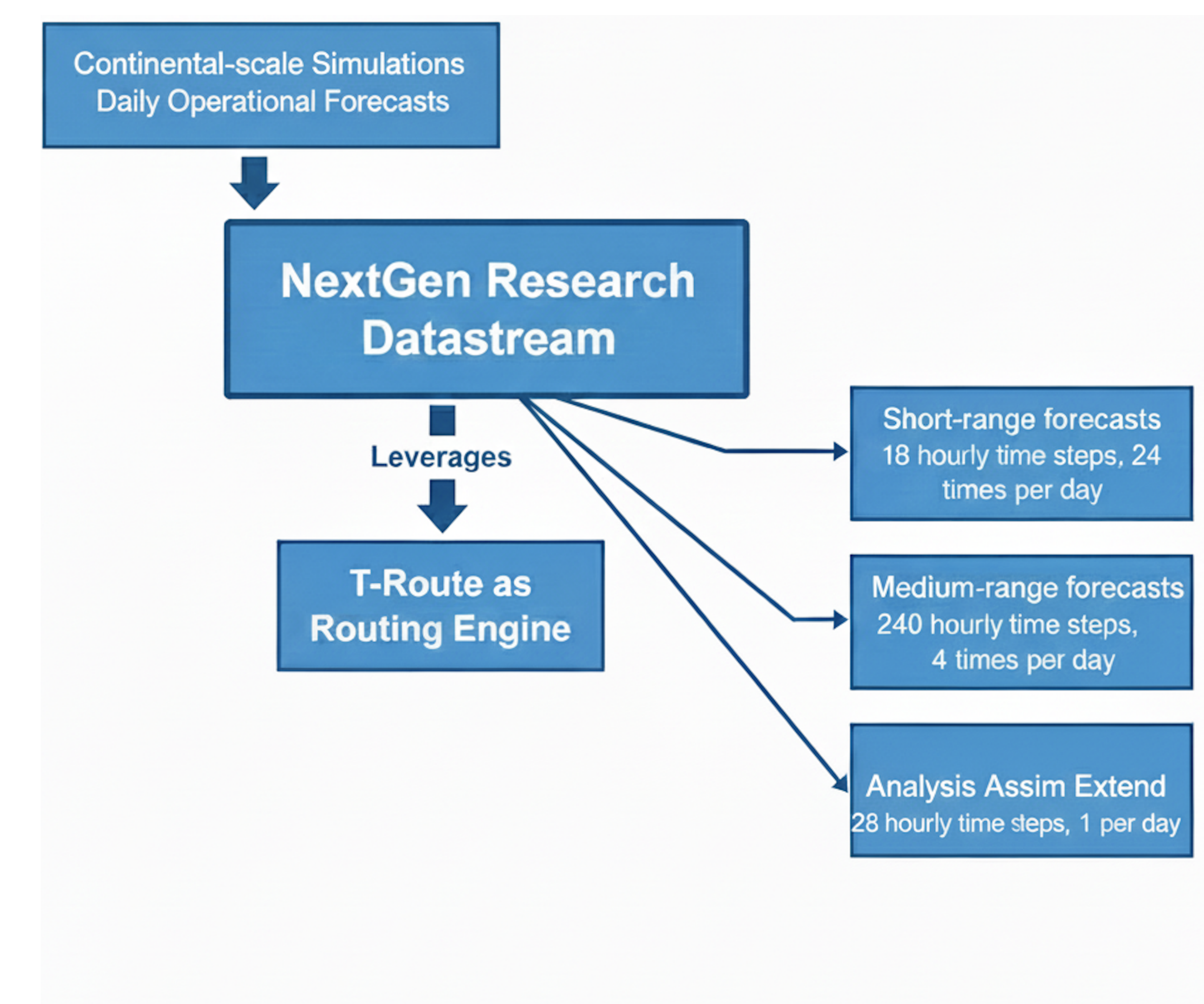

Figure 8. T-route in Nextgen Datastream

References

[1] Thomas H. Cormen et al. *Introduction to Algorithms*. 3rd ed. Cambridge, MA: MIT Press, 2009. ISBN: 978-0-262-03384-8.

Repository Links

Figure 9. T-route

Figure 10. Next-Gen Research Datastream

Figure 11. CIROH NGIAB website

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