

A Raster-Vector Hydrologic-Hydrodynamic Modeling Framework for Regional Applications with SWOT and Multi-Source Data Integration:

Toward Effective Bathymetry Learning

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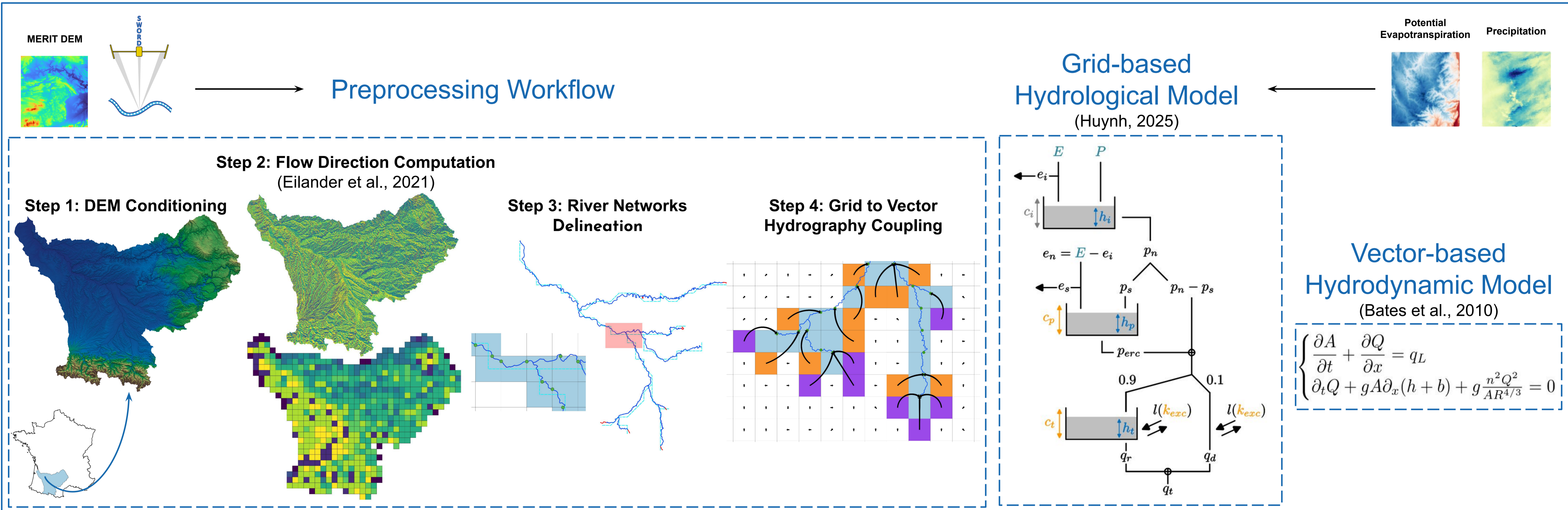
CONTEXT

- **Hydrological-Hydraulic models (H&H):** a key tool for basin-scale physically coherent discharge-water level modeling and heterogeneous data integration and flood-drought hazard assessment, yet hindered by parameter estimation challenges in data-sparse regions, particularly for river bathymetry and hydraulic friction.
- **Multi-source Data Assimilation:** multi-source water surface observations (SWOT, ICESat-2, LiDAR, drone, in-situ) enable hydraulic parameter inference through data assimilation (Larnier et al. 2025), with H&H frameworks offering partial closure to the ill-posed discharge inverse problem at reach scale by providing hydrologically consistent inflows, enabling physically coherent bathymetry-friction estimation and enhancing modeling accuracy in data-sparse regions.

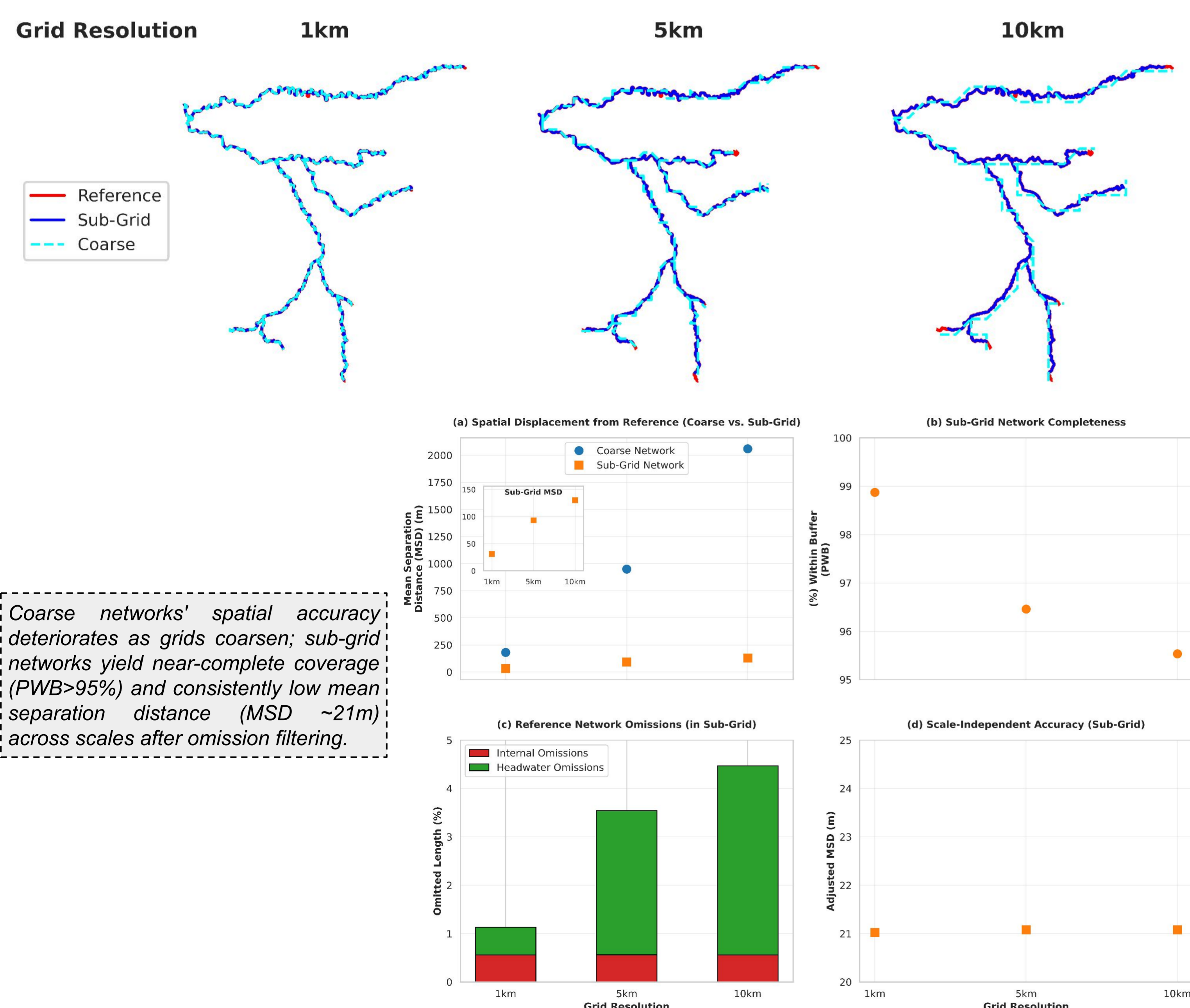
What methodological framework and spatial structure should be adopted for a multi-scale, consistent H&H modeling approach, capable of efficiently assimilating multi-source data to infer key model parameters?

DATA & METHODOLOGY

Proposed Integrated H&H Modeling Framework (smash.recover.inrae): addresses scale mismatches by seamlessly coupling coarse-grid hydrology to fine-scale vector river routing through consistent flux exchange points (upstream and lateral inflows), ensuring mass conservation from hydrology to hydraulics and opening pathways for backward feedback from hydraulics to hydrology (Pujol et al. 2022).

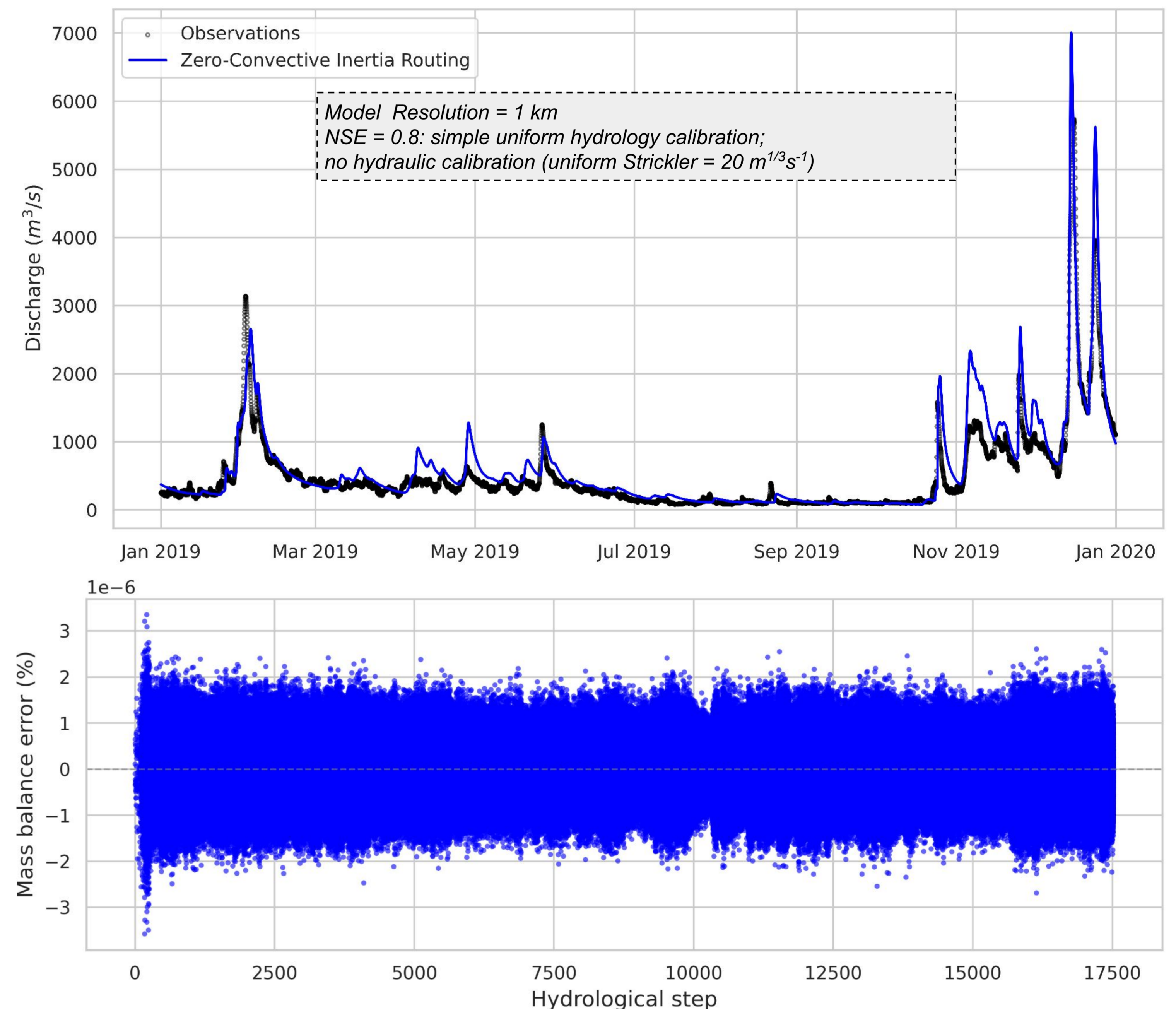


SCALE-CONSISTENT RIVER NETWORKS



➤ Sub-grid representation effectively decouples river network quality from computational grid resolution maintaining high spatial accuracy across scales with minimal omissions (<5%).

EFFECTIVE H&H MODELING FRAMEWORK



➤ Faithful reproduction of basin-scale dynamics using uniform friction and simplified geomorphological channel geometry, with excellent mass balance conservation through effective direct coupling.

CONCLUSIONS & PERSPECTIVES

- **Proof of Concept:** scalable hybrid H&H modeling framework maintaining high spatial accuracy of river networks across scales, paving the way for computationally efficient large-scale hydrological-hydrodynamic modeling.
- **Ongoing Work:** assimilation of multi-satellite data for inferring effective bathymetry-friction consistently at network scale, with extension toward a learnable regionalization framework.

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