



Promoting Open and Transparent Hydrologic Modeling

Many open-source workflows, tools and self-contained modules exist. These can promote efficiency, transparency and collaboration along all steps in the hydrologic modelling chain. Example modelling workflow below, tools on the sides.

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Data-driven forecasting

FROSTBYTE: A reproducible data-driven workflow for probabilistic seasonal streamflow forecasting in snow-fed river basins across North America

Authors: Louise Arnal, Martyn Clark, Ashley van Beusekom, Wouter Knoben, David R. Casson, Paul H. Whitford, Vincent Fortin, Andrew W. Wood, Wouter J. M. Knoben, Brandt W. Newton, and Colleen Watford

Access: <https://github.com/CH-Earth/FROSTBYTE/>

- Regime classification**: Cluster statistics are computed on daily streamflow observations to identify flow regimes. The flow regime is then used to select the most appropriate SWE - Q data.
- Streamflow pre-processing**: Daily streamflow observations are aggregated to seasonal values.
- SWE pre-processing**: SWE observations are processed to generate a time series of SWE anomalies. This is done by subtracting the long-term SWE from the SWE observations and then normalizing the result.
- Forecasting**: New ensemble volume hydrographs are generated for the 1st and 2nd months between Jan and Sep, using Principal Component Regression.
- hindcast verification**: Deterministic and probabilistic verification metrics are computed to measure various aspects of the forecast quality, with bootstrapping.

Environment and Climate Change Canada / Environnement et Changement climatique Canada

Workflows

Water Resources Research

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Community Workflows to Advance Reproducibility in Hydrologic Modeling: Separating Model-Agnostic and Model-Specific Configuration Steps in Applications of Large-Domain Hydrologic Models

W. J. M. Knoben, M. P. Clark, J. Bales, A. Bennett, S. Gharari, C. B. Marsh, B. Nijssen, A. Pietroniro, R. J. Spiteri, C. Tang, D. G. Tarboton, A. W. Wood

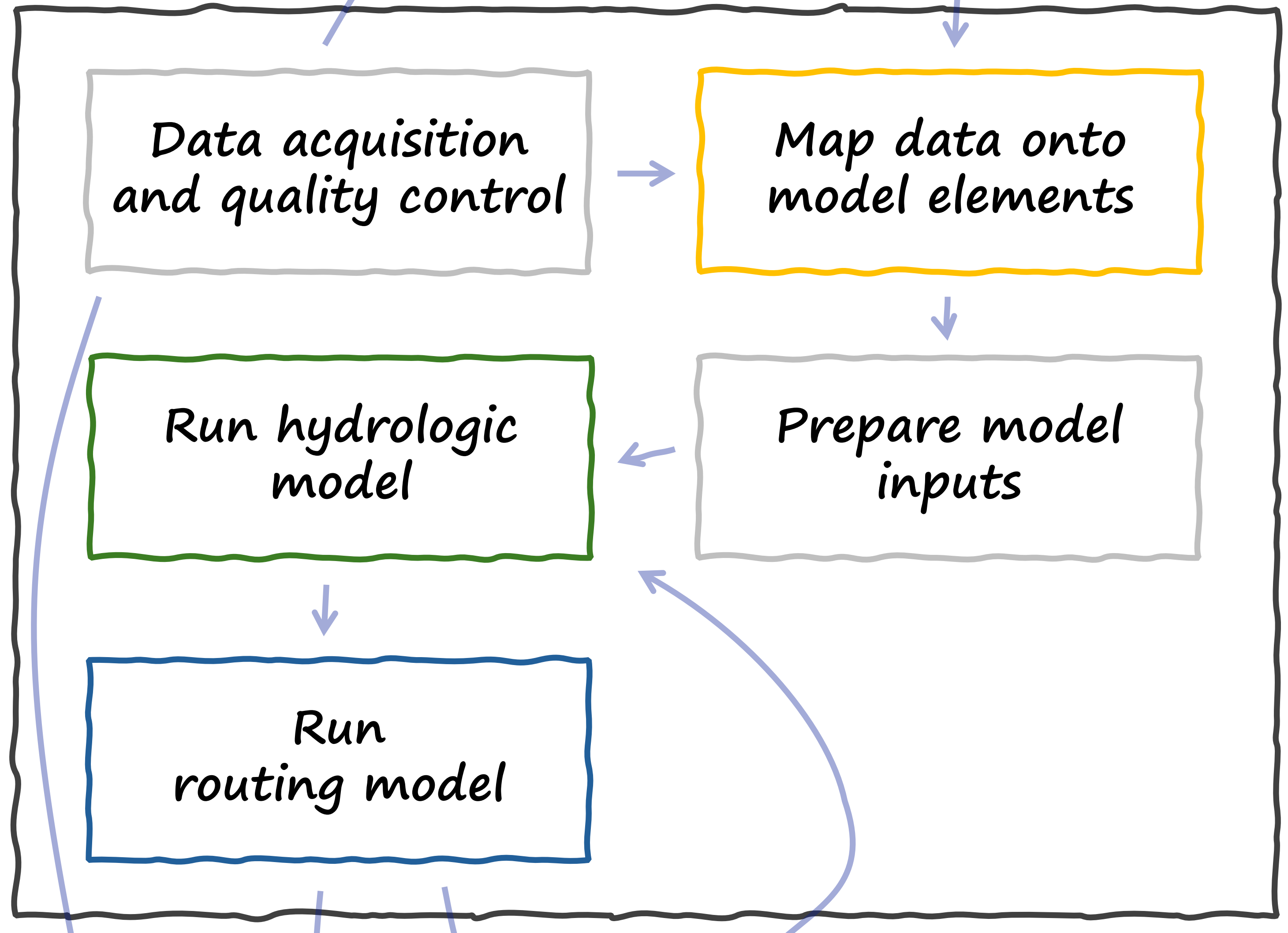
Access: <https://github.com/CH-Earth/CWARHM/>

- WORKFLOW PREPARATION**: Goal: Initialize workflow execution. Action: Create data folder structure separate from code folder. Make domain discretization accessible. Define workflow settings.
- MODEL-AGNOSTIC PREPROCESSING**: Goal: Prepare meteorological and geospatial input data. Action: Download raw meteorological and geospatial data. Data-specific processing (e.g., set consistent Coordinate Reference Systems, ensure standard file formats). Subset data to domain of interest.
- (OPTIONAL) REMAPPING**: Goal: Unify spatial discretization of data and model. Action: Map preprocessed input data onto model elements (e.g., re-grid, grid-to-polygons, etc).
- MODEL-SPECIFIC PREPROCESSING**: Goal: generate simulations with chosen models and data. Action: Convert model-agnostic input data to model-specific input files. Install model(s). Run model(s) to generate simulations.
- ANALYSIS AND VISUALIZATION**: Goal: Answer questions of interest. Action: Analyze model simulations. Visualize findings.

Enhancements:
- Snakemake workflow management (Dave)
- Model Agnostic Framework (Alain, Kasra)



Divide area of interest into model elements



Spatial discretization

Authors: Andy Wood, Hongli Liu
Python code to process forcing data and delineate Hydrologic Response Units (HRUs)
Access: https://github.com/NCAR/watershed_tools

Data remapping

EASYSORE: A Python package to streamline the remapping of variables for Earth System models

Authors: Shervan Gharari, Kasra Keshavarz, Wouter J.M. Knoben, Gouping Tang, Martyn P. Clark

- Python package to map data from one spatial configuration to another
- Multiple workflow examples available
- Access: <https://github.com/ShervanGharari/EASYSORE>
- pip install easysore

Numerical implementation

Improved numerical solvers: SUNDIALS

Figure 6: Error matrix for average routed runoff by GRU; the colorbar maximum is truncated for clarity.

Improved parallelization: The Actors model

Improving modularity and interoperability: Code refactoring

- Object-oriented approaches in Fortran
- Initialize/finalize steps allow generalized interfacing
- Works with any data structures desired
- Concise and modular code

Initialize: Interface with NextGen, Load class objects with model variables

Update: SUMMA flux call, Flux calculation

Finalize: Unload class objects to model variables, Interface with NextGen

Access: <https://github.com/LLNL/sundials>, <https://git.cs.usask.ca/kck540/SummaActors>, https://github.com/seantrim/summa/tree/dev/velop_refactor_Newton

SUNDIALS: Spiteri et al. (JAMES, under review)
Actors: Klenk & Spiteri (Cluster Computing)
Refactor: Trim et al. (in prep)

Sensitivity analysis

Water Resources Research

Method | Open Access | DOI

An Improved Copula-Based Framework for Efficient Global Sensitivity Analysis

Authors: Hongli Liu, Martyn P. Clark, Shervan Gharari, Razi Shekholeslami, Jim Freer, Wouter J. M. Knoben, Christopher B. Marsh, Simon Michael Papalexiou

First published: 22 January 2024 | <https://doi.org/10.1029/2022WR033008>

- Python package to estimate Sobol' sensitivity indices from existing simulations
- Computationally frugal
- Access: <https://github.com/CH-Earth/pyviscous>
- pip install pyviscous

Part A: Data preparation: Select input-output data, Normalize selected data, Calculate empirical marginal CDF.

Part B: GCMC inference: Loop multiple candidate Gaussian components, For each K, estimate GCMC parameters via EM, Calculate AIC score for the estimated GCMC, Identify the best fitted GCMC with the min AIC.

Part C: Sensitivity index estimation: Generate Monte Carlo samples from the best fitted GCMC, Calculate Sobol' sensitivity index.

Lakes and reservoirs

Impact of Lakes and Reservoirs on Streamflow Globally

Figure 1: Global map showing the impact of lakes and reservoirs on streamflow.

Access: <https://doi.org/10.5194/gmd-15-4163-2022>

Evaluating a reservoir parametrization in the vector-based global routing model mizuRoute (v2.0.1) for Earth system model coupling

Authors: Inne Vanderkelen, Shervan Gharari, Naoki Mizukami, Martyn P. Clark, David M. Lawrence, Sean Swenson, Yashu Pokhrel, Naota Hanasaki, Ann van Griensven, and Wim Thiery

A Flexible Multi-Scale Framework to Simulate Lakes and Reservoirs in Earth System Models

Authors: S. Gharari, Inne Vanderkelen, Andrew Tefs, Naoki Mizukami, Erik Kluzek, Tricia A. Stadnyk, David Lawrence, Martyn P. Clark

Access: <https://github.com/ESCOMP/mizuRoute/>

Previously neglected processes

Water Resources Research

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The Numerical Formulation of Simple Hysteresis Models to Simulate the Large-Scale Hydrological Impacts of Prairie Depressions

Authors: Martyn P. Clark, Kevin R. Shook

First published: 29 November 2022 | <https://doi.org/10.1029/2022WR032694> | Citations: 2

Environmental Modelling & Software

Implementing a parsimonious variable contributing area algorithm for the prairie pothole region in the HYPER modelling framework

Authors: Mohamed Jomel Ahmed, Kevin Shook, Alain Pietroniro, Tricia Stadnyk, John W. Bromley, Charlotte Pezza, David Gustafsson