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How fast can a MARRMoT run? Improving runtimes for the Modular Assessment of Rainfall-Runoff Toolbox (MARRMoT)

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Abstract: Since its introduction in 2019, the Modular Assessment of Rainfall-Runoff Toolbox (MARRMoT; Knoben et al., 2019; Trotter et al., 2022) has seen adoption by several hydrological research groups globally. MARRMoT allows users to directly compare 46 commonly used conceptual rainfall-runoff models, and its modular design allows systematic testing of model components in a controlled environment. However, it is slow—a direct consequence of the selected method for solving model equations at each timestep, which was adopted for stability and reliability rather than speed. This research explores two methods for speeding up MARRMoT, focusing on different aspects of the typical MARRMoT workflow:

- Speed up method #1: Replacing the existing solving scheme at each timestep, called the Implicit Euler scheme, with a quadratic approximation whose equations are amenable to analytical solution for each timestep, reducing the need for costly iterative procedures. The quadratic approximation scheme was developed earlier and is named Quadratic Solution of the Approximate Reservoir equation (QuaSoARe; Lerat et al, 2025).

- Speed up method #2: Replacing the existing calibration scheme, a stochastic evolutionary scheme called CMA-ES, with a quasi-Newton approach that more directly uses the local gradient of the objective surface, hopefully leading to faster convergence on the global optimum.

Results indicate modest gains in MARRMoT speed to date, and the potential for future gains from ongoing research. The quadratic solution, QuaSoaARe, is approximately 50% faster than the current method in initial tests, but further effort is required to quantify gains for more complex models (because MARRMoT runtime rises non-linearly with model complexity). For method 2, the quasi-Newton method is more efficient than CMA-ES: about 30% faster for comparable accuracy. Overall, these results indicate potential for improvement, including the idea of combining both methods for greater overall gains. Ongoing research will focus on broadening the range of tests to better represent the use cases experiencing abnormally long run times—typically, complex models applied in arid or intermittent catchments.

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