

Figure 1: (A) Fork-join parallel model. The master thread executes sequential operations and initiates thread forks used in parallel regions. (B) GPGPU architecture showing the relation of streaming multiprocessors and CUDA cores. The fork-join parallel model is applied to blocks of code being executed by thread processing units on multiple streaming multiprocessors.

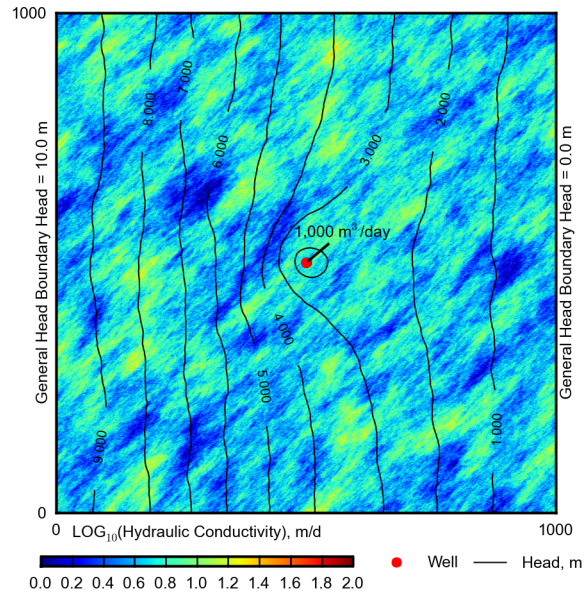


Figure 2: Model domain showing the distribution of hydraulic conductivity and boundary conditions applied to a hypothetical unconfined aquifer. A total of  $1,000 \text{ m}^3/\text{day}$  are withdrawn from 4 pumping wells. Steady-state groundwater head contours (1 m contour interval) are also shown. Note the effect that groundwater withdrawals and hydraulic conductivity are having on simulated groundwater heads.

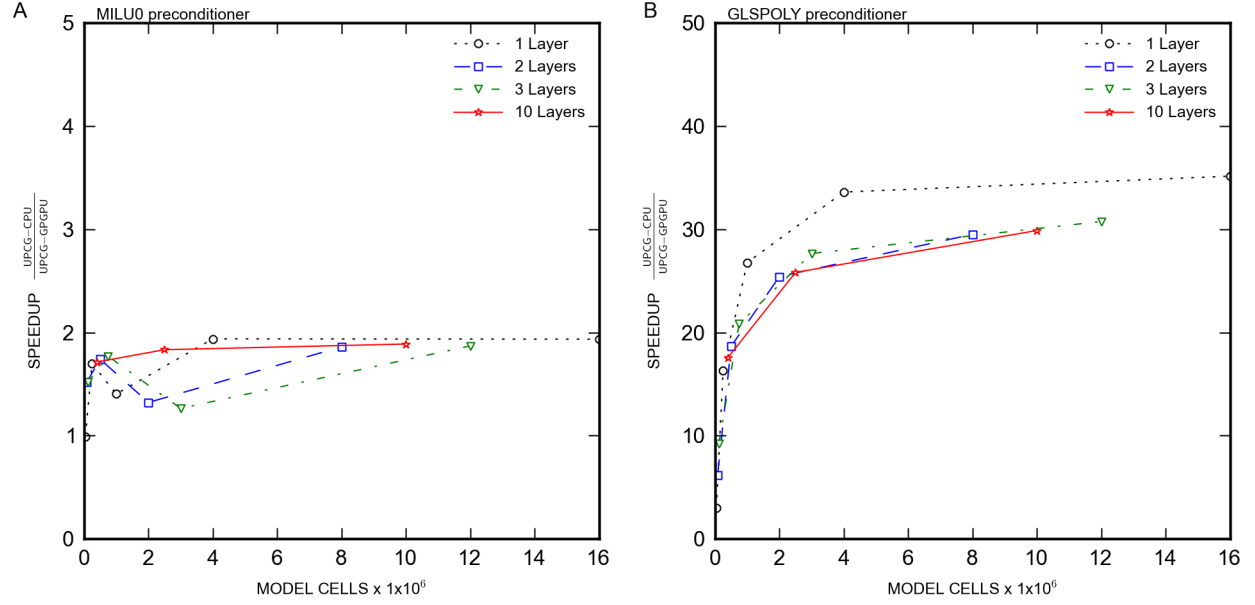


Figure 3: Speedup of UPCG solver GPGPU simulations with the (A) MILU0 and (B) GLSPOLY preconditioners relative to sequential UPCG solver simulations executed on the CPU. Note the different scales used for MILU0 and GLSPOLY speedup.

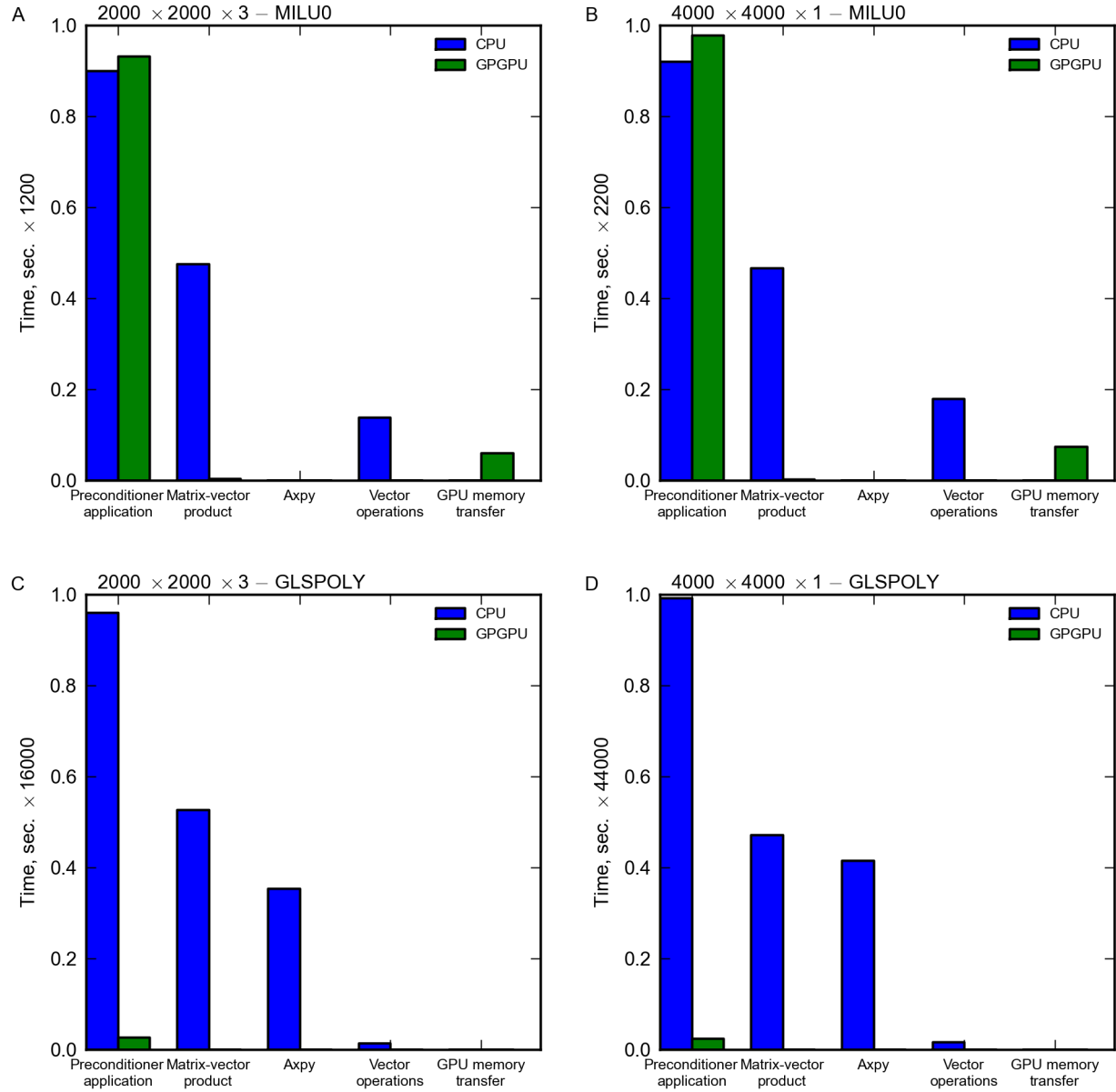


Figure 4: Time, in seconds, spent applying the preconditioner, performing BLAS level 1 operations, and transferring data between the CPU and GPGPU for (A) 2,000  $\times$  2,000  $\times$  3 problem using the MILU0 preconditioner, (B) 4,000  $\times$  4,000  $\times$  1 problem using the MILU0 preconditioner, (C) 2,000  $\times$  2,000  $\times$  3 problem using the GLSPOLY preconditioner, and (D) 4,000  $\times$  4,000  $\times$  1 problem using the GLSPOLY preconditioner. Note operation execution times have been normalized using the maximum preconditioner application time for each problem to facilitate comparison of different model runs.

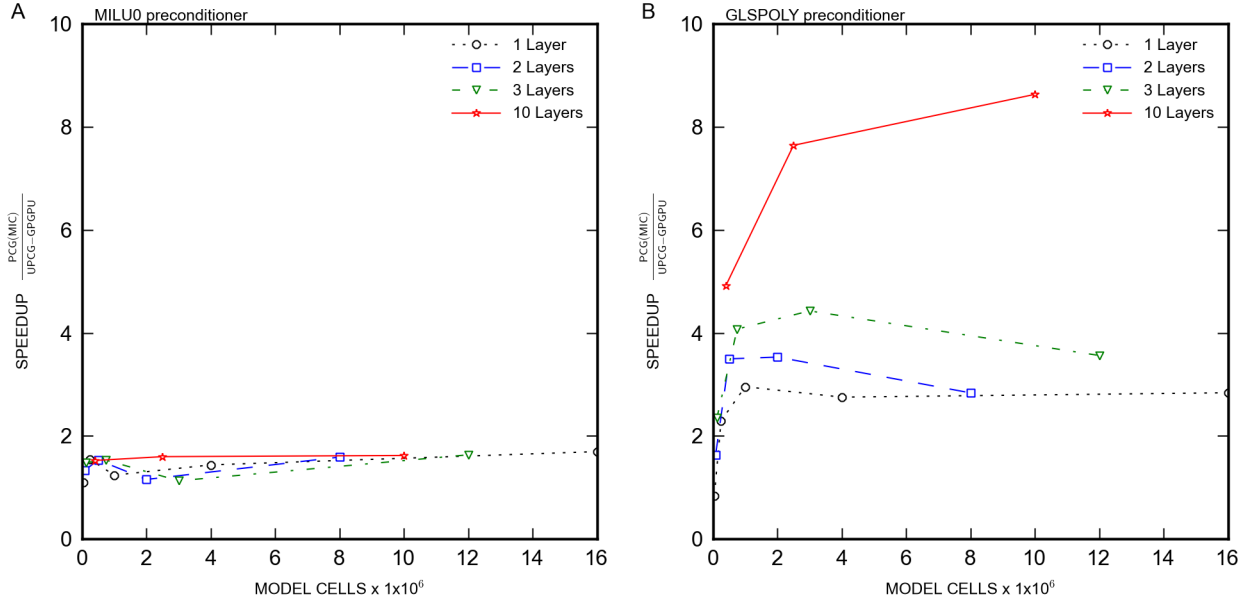


Figure 5: Speedup of UPGC solver GPGPU simulations with the (A) MILU0 and (B) GLSPOLY preconditioners relative to simulations performed using the PCG solver with the modified incomplete Cholesky (MIC) preconditioner.

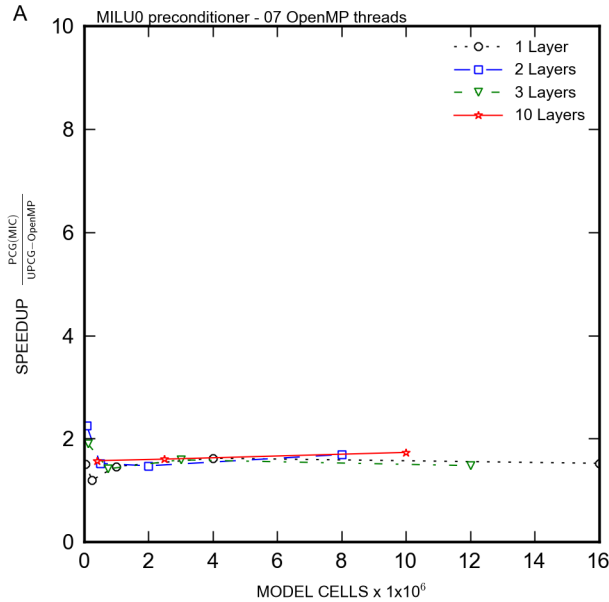


Figure 6: Speedup of parallel CPU simulations using the UPGC solver with the MILU0 preconditioner and 7 threads relative to simulations performed using the PCG solver with the modified incomplete Cholesky (MIC) preconditioner.