HPC needs for Integrated Hydrological Models: examples of application of the GEOtop model to the Vienna Scientific Cluster

Giacomo Bertoldi[a], Samuel Senoner[b], Emanuele Cordano[c], Stefano Endrizzi[d], Matteo Dall'Amico[e], and Stefano Cozzini[f,g]

[a] EURAC Accademia Europea Bolzano, Institute for the Alpine Environment, Bolzano, Italy (giacomo.bertoldi@eurac.edu). [b] EURAC Accademia Europea Bolzano, Organization and Information and Communication Technologies Department, Bolzano, Italy. [c] Rendena100, Engineering and Consultancy sole proprietorship, Tione di Trento, Italy. [d] Independent specialist in hydrology, Zurich, Switzerland. [e] MobyGIS Srl, Trento, Italy. [f] CNR/IOM, Trieste, Italy [g] eXact lab Srl, Trieste, Italy

In this contribution, we would like to review the HPC needs for modern Integrated Hydrological Models, and to show some recent applications of our research using the Vienna Scientific Cluster.

Integrated hydrologic modeling systems simulate complex interactions between groundwater, surface water flows, vegetation and atmosphere under heterogeneous conditions, when nonlinear processes across various space and time scales influence hydrologic response. The mathematical representation of these interactions in simulation models is still a great challenge, because of the composite physical processes described by non-linear, coupled partial differential equations. Therefore, the application of Integrated Hydrologic Models to large domains or long time series (i.e. climate research) requires significant computational efforts. Moreover, such a models cannot be validated easily in the classical sense (i.e., comparison with analytical solutions), in the case of realistic problems [1]. Thus, uncertainty remains in the attribution of hydrologic responses (e.g., correspondence to actual processes) to model structural errors (e.g., missing processes, such as water use), and initial and boundary conditions (e.g., complex domains). For this reason, tools for uncertainty quantification and optimal parameters identification are essential. The need of multiple optimization runs implies also large computational needs.

In this contribution, we present an application of the GEOtop 2.0 model [2], where a model sensitivity analysis has been performed for several experimental stations located in the Alps, representative of different conditions in terms of topography (elevation, slope, aspect), land use (pastures, meadows, and apple orchards), soil type and groundwater influence. A new automatic sensitivity and optimization tool based on the Particle Swarm Optimization theory has been developed. The tool is based on R and has been adapted for VSC to leverage MPI and job arrays. In the talk, we will illustrate details of the implementation under MPI with the VSC. Moreover, possible model structural deficiencies and future research directions to improve computational efficiency will be discussed.

The optimization tool geotopOptim is available as R package on `https://github.com/EURAC-Ecohydro/geotopOptim2` . The GEOtop code is implemented in C/C++ and published on its own github repository `http://geotopmodel.github.io/geotop/` under GPL v3.0 license. The software is also complemented by several tools, which provide web-based visualization of results based on R plugins as geotopbricks, which allow rapid and efficient scientific validation of results and tests.

References

[1] Kollet, S., Sulis, M., Maxwell, R., Paniconi, C., Putti, M., Bertoldi, G., ..., Sudicky, E. (2016). The integrated hydrologic model intercomparison project, IH-MIP2: A second set of benchmark results to diagnose integrated hydrology and feedbacks. Water Resources Research. https://doi.org/10.1002/2016WR019191

[2] Endrizzi, S., Gruber, S., Dall'Amico, M., and Rigon, R.: GEOtop 2.0: simulating the combined energy and water balance at and below the land surface accounting for soil freezing, snow cover and terrain effects, Geosci. Model Dev., 7, 2831-2857, doi:10.5194/gmd-7-2831-2014, 2014.