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# Adaptive Conservative Time Integration with Higher Order Schemes for Transport in Fractured Porous Media

*Thursday, 2 June 2022 11:50 (15 minutes)*

When transport (or any other hyperbolic partial differential equation) is solved with explicit time integration in a finite volume method (FVM), the Courant-Friedrichs-Levy (CFL) number needs to be below a critical value in order to ensure stability and accuracy. The CFL criterion provides an upper bound of the time step for every grid cell. In conventional methods, where the same time step is used for all grid cells, the lowest value of this upper bound is chosen as the global time step. When advection speed and/or grid spacing vary considerably throughout the domain, this can lead to unnecessary computational cost because many cells could be integrated with a much larger time step.

Various local time stepping methods have been developed which overcome this drawback by using customized step sizes for each cell. The adaptive conservative time integration (ACTI) scheme is a local time stepping method recently developed by Jenny (2020). The basis for this scheme is that all local time steps $\Delta t_I$ are fractions of the global time step by powers of two, i.e., $\Delta t_I = \Delta t_{\text{Global}}/2^{L_I}$, where the integer variable $L_I \geq 0$ denotes the time refinement level of a particular grid cell. The grid cells are synchronized after each global time step and strict conservation at the global time resolution is guaranteed.

For tracer transport in two-dimensional discrete fracture and matrix models we demonstrate that ACTI reduces the computational cost by orders of magnitude compared to global time stepping. We obtain excellent results with a first-order upwind scheme which is still widely used in many applications. However, we notice that a combination of ACTI with a standard higher-order MUSCL scheme can lead to spurious oscillations in the solution even though this flux scheme is stable in combination with global time stepping. In this work, we study the influence of different slope limiters on the solution stability, and we propose a modified MUSCL scheme relying on advection of an inclined reconstruction (MUSCL-AIR). Empirically, we show that a more dissipative slope limiter can reduce the spurious oscillations that arise with the standard MUSCL scheme, albeit at the cost of slightly more diffusive concentration fronts. Combining ACTI with MUSCL-AIR results in accurate and stable solutions independent on the choice of slope limiter. This combination is therefore ideally suited for tracer transport in fractured porous media, but it is also very attractive for other applications where advection speed and/or grid spacing vary throughout the domain and a higher-order transport scheme is desired.

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## References

JENNY, P. 2020. Time adaptive conservative finite volume method. Journal of Computational Physics, 403, 109067. doi: 10.1016/j.jcp.2019.109067

## Time Block Preference

Time Block B (14:00-17:00 CET)

## Participation

Unsure

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