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# Efficient in-situ visualization of unsteady flows in climate simulation

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The simulation of climate data tends to produce very large data sets, which hardly can be processed in classical post-processing visualization applications. Typically, the visualization pipeline consisting of the processes data generation, visualization mapping and rendering is distributed into two parts over the network or separated via file transfer. Within most traditional post-processing scenarios the simulation is done on a supercomputer whereas the data analysis and visualization is done on a graphics workstation. That way temporary data sets with huge volume have to be transferred over the network, which leads to bandwidth bottlenecks and volume limitations. The solution to this issue is the avoidance of temporary storage, or at least significant reduction of data complexity.

Within the Climate Visualization Lab – as part of the Cluster of Excellence "Integrated Climate System Analysis and Prediction" (CliSAP) at the University of Hamburg, in cooperation with the German Climate Computing Center (DKRZ) – we develop and integrate an in-situ approach. Our software framework DSVR is based on the separation of the process chain between the mapping and the rendering processes. It couples the mapping process directly to the simulation by calling methods of a parallelized data extraction library, which create a time-based sequence of geometric 3D scenes. This sequence is stored on a special streaming server with an interactive post-filtering option and then played-out asynchronously in a separate 3D viewer application. Since the rendering is part of this viewer application, the scenes can be navigated interactively. In contrast to other in-situ approaches where 2D images are created as part of the simulation or synchronous co-visualization takes place, our method supports interaction in 3D space and in time, as well as fixed frame rates.

To integrate in-situ processing based on our DSVR framework and methods in the ICON climate model, we are continuously evolving the data structures and mapping algorithms of the framework to support the ICON model's native grid structures, since DSVR originally was designed for rectilinear grids only. We now have implemented a new output module to ICON to take advantage of the DSVR visualization. The visualization can be configured as most output modules by using a specific namelist and is exemplarily integrated within the non-hydrostatic atmospheric model time loop. With the integration of a DSVR based in-situ pathline extraction within ICON, a further milestone is reached. The pathline algorithm as well as the grid data structures have been optimized for the domain decomposition used for the parallelization of ICON based on MPI and OpenMP. The software implementation and evaluation is done on the supercomputers at DKRZ. In principle, the data complexity is reduced from O(n3) to O(m), where n is the grid resolution and m the number of supporting point of all pathlines. The stability and scalability evaluation is done using Atmospheric Model Intercomparison Project (AMIP) runs.

We will give a short introduction in our software framework, as well as a short overview on the implementation and usage of DSVR within ICON. Furthermore, we will present visualization and evaluation results of sample applications.