Cluster-based parallelization of simulations on dynamically adaptive grids on the sphere

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The execution of numerical simulations on dynamically changing grids belongs to the major challenges in high-performance computing. Here, a steadily changing grid structure imposes requirements on a valid connectivity information and, due to load imbalances, requires efficient data migration. We tackled both issues with a partitioning based on SFC intervals which are induced by splits of the spacetree and a run-length encoded (RLE) connectivity information. This RLE connectivity information is only stored for the partition's shared hyperfaces. We further call such a parallelization and communication scheme *clustering*.

This clustering yields several advantages with the major ones summarized here: (a) keeping the connectivity information in a consistent state can be accomplished by communicated adaptivity refinement and coarsening markers, (b) splitting and joining clusters is based on stack-inferred information and (c) data migration is highly efficient due to only migrating the simulation and structure information which is stored on streams and requires updating RLE meta information only.

Regarding the parallelization, this is contrary to classical partitioning approaches with typically only a single partition per rank. With our clustering, we can store several partitions per rank (decomposition of a partition into clusters) and use shared-memory parallelization models efficiently. With the RLE communication scheme, this further results in an en bloc communication for distributed-memory parallelization models and a cluster-based data migration to tackle the load imbalances.

This parallelization approach results in high scalability on shared- as well as distributed-memory systems. Using a forest of spacetrees, we extend our simulation to a cubed sphere and are hence able to execute simulations on a dynamically changing grid on a sphere (see Fig. 1).

Our work is based on the bisective Sierpiński curve and is also applicable to other SFC-induced grids such as Cartesian grids and hexagonal grids.

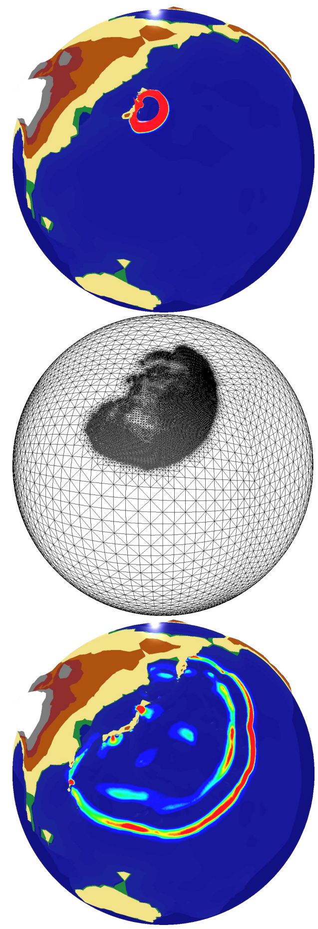

Figure 1: Online visualization of finite volume simulation of Tohoku Tsunami with augmented Riemann solvers [1] (Developed in collaboration with Alexander Breuer)

References

[1] David L George. Augmented riemann solvers for the shallow water equations over variable topography with steady states and inundation. *Journal of Computational Physics*, 227(6):3089–3113, 2008.