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High resolution 3D modeling of heterogeneous parabolic and hyperbolic problems on structured meshes.

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Complex geometries found in geological setups are often modeled by body fitting meshes. Numerical methods for unstructured grids can provide better accuracy with lower resolution. However, when dealing with large, three dimensional problems these approaches are computationally expensive and structured grids may be a better choice. Cheap methods specially developed for structured grids, such as Fractional Steps/ADI, can be applied as efficient implicit solvers. Other advantages are smaller memory requirements and higher per-CPU computational efficiency, both due to the known grid structure. These factors facilitate calculations on high-resolution, three dimensional models.

An efficient implementation of Alternating Direction Implicit/Locally One Dimensional schemes for an Opteron-based shared memory system is presented. In the implementation, the memory bandwidth usage, the main bottleneck on modern computer architectures, is specially addressed. High efficiency of above 2 GFlops per CPU is sustained for problems of 1 billion degrees of freedom. The optimized sequential implementation of 1D sweeps is comparable in execution time to copying the data in the memory. Scalability of the parallel OpenMP implementation on up to 8 CPUs is close to perfect. Performing one timestep of the Locally One Dimensional scheme on a system of 1000ˆ3 unknowns takes only 11 seconds.

In our work we address mainly transient problems. A comparison between structured and unstructured approaches is first shown. An MPI, massively parallel implementation of elastic wave propagation for unstructured meshes using the Finite

Element Method is compared to a structured staggered grid approach on the example of wave scattering around an ellipsoidal heterogeneity. Analogous tests are performed for the parabolic solver. Finally, we present an application of operator splitting methods to transient parabolic and hyperbolic problems using high-resolution, real-world oil reservoir data.