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PRECONDITIONED IMPLICIT RUNGE-KUTTA SCHEMES FOR UNSTEADY SIMULATIONS OF LOW MACH NUMBER COMPRESSIBLE FLOWS

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Abstract. An extensive literature review of low Mach Preconditioned Density-Based Methods reveals that physical-time marching is almost always performed with a second-order BDF scheme. As far as the author is aware, the second-order Crank-Nicolson scheme has been the only notable but very rare exception. In other words, these methods have always employed some form of multi-step scheme in physical-time. Since these schemes loose unconditional linear stability when their order is increased above two, simulations with this method have been essentially restricted to second-order accurate in time. The present paper demonstrates for the first time how the traditional dual-time stepping procedure naturally leads to the low Mach preconditioning of the intermediate stage variables within implicit Runge-Kutta schemes. Such an extension allows the use of high-order multi-stage schemes by this method. Second, third and fourth-order diagonally implicit Runge-Kutta schemes are employed under this new methodology to simulate vortex formation in absolutely unstable planar mixing-layers, providing strong evidence of its capabilities. Results indicate that, as it should be expected, high-order multi-stage schemes with strong linear numerical stability outperform traditional lower order multi-step schemes when stringent tolerance requirements are imposed.

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