J. Reisner

A fully-implicit hurricane model with physics-based preconditioning

Los Alamos National Laboratory
Mail Stop D401/EES-2
Los Alamos
NM 87545
reisner@lanl.gov
V. Mousseau
A. Wyszogrodzki
Knoll, D.

A numerical framework for simulating hurricanes based upon solving a nonlinear equation set in a consistent manner without time splitting is described in this paper. The physical model is the Navier-Stokes equations plus a highly simplified and differentiable microphysics parameterization package. Because the method is fully implicit, the approach is able to employ time steps that result in Courant-Friedrichs-Lewy (CFL) numbers greater than one for advection, gravity, and sound waves; however, the dynamical time scale of the problem must still be respected for accuracy. The physical model is solved via the Jacobian-Free Newton-Krylov (JFNK) method. The JFNK approach typically requires the approximate solution of a large linear system several times per time step. To increase the efficiency of the linear system solves, a physics-based preconditioner has been employed. To quantify the accuracy and efficiency of the new approach against traditional time-split approaches, the fully-implicit solver was first compared against the semi-implicit approach for the simulation of a precipitating moist bubble. The moist-bubble simulations not only demonstrated the ability of the fully-implicit approach to achieve second-order accuracy in time, but also the ability of the fully-implicit approach to achieve a given level of accuracy in a more efficient manner than traditional approaches. This behavior is further illustrated in first-of-a-kind three-dimensional fully-implicit hurricane simulations that reveal the semi-implicit algorithm needs to take a time step at least 60 times smaller than the fully-implicit algorithm to produce a comparable change in the intensity of a hurricane.