Dual field mass-, energy-, and helicity conserving discretization for the incompressible Navier-Stokes equations

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We introduce a mimetic dual-field discretization which conserves mass, kinetic energy and helicity for three-dimensional incompressible Navier-Stokes equations. The discretization makes use of a conservative dual-field mixed weak formulation where two evolution equations of velocity are employed and dual representations of the solution are sought for each variable. A temporal discretization, which staggers the evolution equations and handles the nonlinearity such that the resulting discrete algebraic systems are linear and decoupled, is constructed. The spatial discretization is mimetic in the sense that the finite dimensional function spaces form a discrete de Rham complex. Conservation of mass, kinetic energy and helicity in the absence of dissipative terms is proven at the discrete level. Proper dissipation rates of kinetic energy and helicity in the viscous case is also proven. Numerical tests supporting the method are provided.