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A numerical study on the time-varying attitudes and aerodynamics of freely falling conical graupel

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The flow fields and dynamic motions of conical graupel of diameters 0.5-5mm falling in air of 800 hPa and -20˚C are studied by solving the transient Navier-Stokes equations numerically for flow past the conical graupel and the body dynamics equations representing the 6-degrees-of-freedom motion that determines the position and orientation of the graupel in response to the hydrodynamic force of the flow fields. The shape of conical graupel made through a simple but practical existing mathematical equation allows us to have an uneven mass distribution, which is generally believed to have great influence on ice particles' orientations while falling when inertial force becomes increasingly dominant over other effects. The simulated motions include vertical fall, lateral translation, sailing, rotation and pendulum swing. The computed flow fields are characterized in terms of streamtrace patterns as well as the vorticity magnitude fields, and the corresponding motion of the conical graupel is physically featured by looking upon the graupel surface distributions of pressure coefficient, torques contributed by both pressure as well as viscous effects. Tumbling occurs when an initial orientation of the graupel is 160˚ about Y axis, and the torque contributed by the pressure effect is dominant over that contributed by the viscous effect.