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Aviation hazards associated with topographically-forced rotors

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When stably stratified air is forced to rise over a topographic barrier, mountain waves are generated and radiate away from the barrier. Mountain waves may be accompanied by severe downslope winds near the surface, occasionally in excess of 50 m s-1, that rapidly decelerate in the lee and flow back toward the mountain as part of an intense circulation. These vortices, known as rotors, can be severe aeronautical hazards due to intense wind shear and have been cited as contributing to numerous aircraft accidents, including occurrences involving modern commercial and military aircraft.

The characteristics of rotors forced by three-dimensional topography are investigated through a series of high-resolution real data simulations (333 m horizontal grid increment) and idealized Large Eddy Simulation (LES) experiments (isotropic resolution of 60 m) with the non-hydrostatic COAMPS model. The focus of this investigation is on the internal structure of rotors and in particular on the dynamics of small-scale intense circulations within rotors that we refer to as "sub-rotors". The characteristics of rotors and sub-rotors and the implication for aviation safety will be addressed. Idealized LES experiments indicate a thin sheet of high-vorticity fluid develops adjacent to the ground along the lee slope and then ascends abruptly as it is advected into the updraft at the leading edge of the first trapped lee wave. Sub-rotor circulations develop along the leading edge of the "parent" rotor due to parallel-shear instability. The intense sub-rotor circulations along the leading edge of the rotor represent the most significant aviation hazard. Results will be presented for real data simulations of two cases of aircraft encounters of turbulence in the lee of the Sierra Nevada Range associated with wave breaking and rotors including an event that took place during the Sierra Wave Project in 1955.