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Influence of aerosol deposition on snowpack evolution in simulations with the ORCHIDEE land surface model

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Simulating seasonal snow with state-of-the-art global general circulation models (GCMs) is still challenging. Snow provides fresh water to billions of people and plays an important role in the energy budget of the earth through albedo, which affects not only local but also remote and global climate/hydrological patterns. Therefore, changes in snow amount and length of the season are crucial when investigating climate variability. One key aspect often overlooked in GCMs is the inclusion of Light Absorbing Particles (LAPs) in snow simulations. LAPs dramatically reduce snow albedo, particularly for visible solar radiation, leading to considerable implications for climate modeling. The intention is to lay the foundations for addressing the issues across different climate conditions through simulations, by adding the snow darkening effect to a multilayered intermediate complexity scheme within ORCHIDEE, the land surface model embedded in the IPSL Earth System Model.

LAPs are commonly deposited on the surface of fresh snow and progressively become embedded into deeper layers of the snowpack. The LAP species taken into account include four log-normal modes of dust, soot, and organic carbons. These tracers allow for the movement of LAPs through different layers of the snowpack, adjusting with snow accumulation or melting. In order to simulate the movement of LAPs, ORCHIDEE has been enhanced with a tracer flow mechanism that carry LAPs from the top snow layer following deposition and move through various layers as snow thickens or flushes with meltwater flow. Our approach to snow albedo deviates from the default method in ORCHIDEE as a function of snow aging through an exponential decay function with dependence on the degree of water saturation and the occurrence of fresh snow deposition. Instead, it integrates the Warren and Wiscombe snow radiative transfer scheme with Kokhanovsky's single scatter properties of snow crystals and the optical properties of LAPs to compute the albedo of impure snow. This study conducted site-level offline ORCHIDEE simulations using observed atmospheric conditions and MERRA2 aerosol deposition data. The integration of LAPs and related processes has led to improved simulations of seasonal snow, achieving more realistic representations of snow albedo compared to pure snow. Our results also show that LAPs play an important role in determining the local snow season length.