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Onset of thermal convection in a permafrost layered ground cover

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A significant part of the Arctic soil, as a rule, is year-round under a moss cover, to which a layer of snow is added in winter. Moss and snow have high insulation properties and consist of a skeleton (organic and ice, respectively) and air-saturated pores, thus forming one system connected by thermal and dynamic interaction. However, in the presence of a temperature gradient, convection may occur within such a system, which significantly reduces the thermal resistance of the layers and, thereby, influences the upper soil layers temperature regime.
Our work is aimed to studying the occurrence of convective instability in a system of two porous layers with thermally insulated outer boundaries for conditions that approximately correspond to the moss-snow cover of the arctic deserts of the Bolshevik Isl. (Severnaya Zemlya Archipelago). The solution of the Rayleigh-Darcy problem is obtained by the small parameter method, with expanding the perturbation amplitudes of the vertical velocity and air temperature in rows in even powers of the dimensionless wavenumber. When the ratio of the thickness of the lower layer (moss) to the total thickness of the layers (moss and snow) is h (0 <h <1), the critical Rayleigh numbers for the system Ra are functions of the ratio of polynomials of the 1st and 3rd degree relative to h, the coefficients of which are the ratio of the moss and snow characteristics: air permeability K, thermal conductivity k and thermal diffusivity x. The limiting cases h = 0 and h = 1 correspond to the transition to a single-layer system with the properties of moss and snow, for which Ra = 3K/(kx) and Ra = 3; respectively. The dependence of the convective instability threshold on variations of the typical species composition and properties of the vegetation and snow cover of the studied territory, parameterized according to measurements and literature data, is estimated. The qualitative differences of the considered problem are shown in comparison with the similar task for homogeneous liquids. A general procedure for solving the Rayleigh-Darcy problem in the long-wave approximation for a multilayer porous system is formulated, which considers the glaciological aspect of problem. Based on theoretical and experimental data, it was concluded that it is necessary to take into account the contribution of convection in layers of moss and snow to thermal, mass and gas exchange between soil and atmosphere.