Influence of Interannual Variability and Trend Changes in Snow Cover's Structure and Properties on the Thermal Regime of the Underlying Surface

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Contribution of snow cover into thermal interaction between the atmosphere and the lithosphere is determined by its radiative and heat-transfer properties, first of all by heat conductivity of snow that, in turn, depends on its density, structure, and thermal regime. Thickness, structure and properties of snow change with space (regional and local changes) and time (trend and interannual changes in climate conditions, seasonal changes in the process of snow accumulation and metamorphism). These changes in the snow cover's structure, properties and duration affect the heat exchange conditions and cause the corresponding variations in the depth of seasonal freezing of underlying soils and in duration of their frozen state.

Perennial changes of temperature, winter precipitation and thickness of snow cover are accompanied by their interannual (quasi-two-year) variations that are higher than that of trend variations for more than an order of magnitude. In all climatic zones of Russia, correlations between the interannual variation modules of winter values of air temperature, precipitation and snow cover thickness to the corresponding values of trend changes have the similar order of magnitude. This allows to consider (with certain corrections, of course) the interannual anomalies in seasonal snow cover's characteristics as a certain prototype of its response to possible perennial climate changes.

Performance of the regional assessment of the heat and mass exchange of the underlying surface with snow cover and atmosphere will require the data on the snow cover properties and structure (stratigraphy), as well as their possible interannual and spatial variations. These characteristics can be assessed based on the parameters determining water content and average density of the snow layer, possible runoff of melt water generated during thaws, presence of layers and crusts of various geneses (total amount of solid precipitation, snow cover thickness, frequency and duration of snowfalls, thaws, wind and radiation impacts). These parameters, in turn, may be obtained by means of standard meteorological data analysis.

The maps were created showing climate conditions, snow cover thicknesses and their anomalies compared to average perennial values and demonstrating their peculiar changes within the territory of Russia in winter periods of late 20th – early 21st centuries. The identified characteristics include: 1) correlation between changes of temperature and winter precipitation; 2) dependence of snow cover's thickness and density from winter precipitation and temperature.

Simulation of the regional structure and average density of snow cover on the territory of the Russian Federation was based on the maps showing average winter temperature, winter precipitation and frequency of meteorological events: snowfalls, thaws, winds with velocity more than 10 m/s, and surges (exceeding 10ºC) of air temperature in the negative-value area. During map building, we took into consideration the snowfalls with daily intensity more than 0.01 g/sq.cm and thaws with air temperatures rising over 0ºC for more than one day. Model sections are based only on meteorological phenomena that took place during formation of snow cover and do not reflect the timing of events or possible spatial variations of its accumulation on the meso- and micro-levels. Verification of the sectional simulation results performed based on the field observations and published sources showed that, in spite of the schematic nature of model sections, they are identical to actual ones in principle and can be used to identify interannual variations of the snow cover's structure.

Characteristics of winter climate conditions, model sections and identified relations, correlations and dependencies help to estimate average density, heat capacity and heat conductivity of snow cover, as well as its average winter thermal gradient. As a result, it is possible to calculate (re-construct) the heat flow from snow cover and underlying soil to the atmosphere and, if the data on moisture content and thermophysical properties of soil are available, to calculate possible depth of freezing and its interannual variations determined by snow cover.

Calculations for three climatic zones of Russia located near the Polar circle were carried out for the coldest and warmest seasons of the 21st century based on the proposed freezing depth calculating algorithm and program. The obtained results correspond with the field observation data for relevant regions.