Spatial structure of southern taiga landscape energy balance and temperature field based on remote sensing data

R.B. Sandlerskiy^{1, 2}, Yu.G. Puzachenko², D.N. Kozlov¹

¹ Lomonosov Moscow State University Faculty of Geography, 119899, Moscow, Leninskiye Gory 1, Russia, srobert_landy@mail.ru
² A.N. Severtsov Institute of Ecology and Evolution RAS, 119071, Moscow, Leninsky prospect 33, Russia

Remote sensing allows estimating the energetic condition of a terrestrial surface and features of solar energy transformation in ecosystems at the surveying moment. Satellite measurements in the different spectral zone of the reflected solar energy in comparison to a solar constant permit to calculate absorbed solar radiation on unit of a surface, albedo. The image of thermal channel shows the spatial heterogeneity of land cover temperatures.

The most part of the absorbed energy is used for transpiration, biological production, biogeochemical processes, is partially preserved in ground and partially dissipates in the form of thermal radiation. The absorbed energy going on production and circulation of moisture refers as exergy. Exergy is the maximal work which the thermodynamic system can make at transition from the given condition in a condition of balance with environment (Jorgensen, Svirezhev, 2004). Working capacity of system sometimes refers to exergy. Exergy is a function of a distance between the current condition of system and thermodynamic balance condition. Exergy of solar radiation in landscapes cover can be measured through a distance between distribution of capacities on a spectrum of the absorbed solar energy for unit of a surface and an equilibrium condition with hypothetical absorption of a solar energy proportional to distribution of capacities in a spectrum of a solar constant. The degree of a deviation of a real spectrum of absorption from equilibrium spectrum is estimated on the base Kullback's entropy (Jorgensen, Svirezhev 2004). Kullback's entropy is a measure of distinction of two compared distributions, and it is the important physical parameter of the open no equilibrium thermodynamic systems. The more Kullback's entropy, the more exergy. A part of the absorbed energy which is not used for useful work increase the internal energy of ecosystems. This part of absorbed energy passes in energy of molecules movement (heat exchange) and chemical communications (internal energy). The increment of internal energy is estimated on a difference between values of the absorbed energy and the exergy. Thermodynamic characteristics allow estimating character and efficiency of energy transformation in landscape depending on its internal structure.

Calculation of thermodynamic variables is carried out on Landsat 5 and 7 multispectral scenes. Multispectral scanners of these satellites allow to calculate quantity of reflected radiation in a strip of lengths of waves 0.45 - 2.35 microns - for elementary unit of a surface - 28.5 m and thermal long-wave radiation in a strip 10.12 - 14.5 microns (57 m), covering the most part of a solar radiation spectrum. Variables are calculated for five terms of surveying: March, April, May, June, and September at 11 AM o'clock Moscow time. Research is carried out for territory of Central-Forest Biospheres Reserve (33° E, 56.2° N). The landscape properties are in many respects unique (moraine ridge height with boreal spruce and complex spruce forest in a combination with peatlands, windfalls, cutover patches and fields), create a basis for comparison of properties of various types of a surface and their territorial combinations. On five terms of surveying following thermodynamic variables (for each elementary unit of a surface) have been calculated: coming solar energy (W/m²), the reflected solar energy (W/m²), albedo, the absorbed energy (W/m²), temperature of a surface (°C), a share of the absorbed energy spent for

manufacture of biological production (%), a share of the absorbed energy spent on transpiration (%). Average values of variables for various types of a surface are estimated: forests, the agricultural fields and meadows, peatlands, windfalls. Maps of components of energy balance and a field of temperatures with the resolution 30x30 m are created.

Transformation of energy within a landscape for each season has the following features. In the winter condition (March) intensity of a heat flow is substantially determined by absorbed solar energy. As a whole the landcover is as much as possible close to equilibrium, energy is spent for cleanly physical processes. In the summer a landscape is maximal non equilibrium, exergy is maximal and landscape useful work is evapotranspiration and bio-productivity. To distinguish the contribution of energy to these two processes without additional measurements is impossible. During the spring and autumn exergy of solar radiation in landscapes has decrease relatively summer level.

The seasonal changes of thermodynamic variables are identical for different landcover types. They differ only in size of absorbed radiation and exergy. Forests as a whole intensively evaporate water thus old spruce and pine forests under these characteristics come nearer to the open water. Windfalls and young forests have essentially smaller exergy; minimal exergy is at meadows and the agricultural fields. On the average the more temperature of a surface, than less is the exergy. The heat inputs for evaporation are huge for forests of reserve as they are mostly occupied by old spruce forests. The area of reserve is much colder than ambient landscapes with secondary young small-leaved forests alternating with the agricultural fields. Probably that defines mesoclimate and modern features of vegetation and soil covers.

Behavior of thermodynamic variables for peatlands with the area of few square kilometers differs greatly. In the spring and in autumn exergy and nonequilibrium of peatlands is severely greater, than at meadows and the agricultural grounds. In the summer the peatlands has a more equilibrium condition. Useful work and, accordingly, transpiration is lower, than at meadows. Actually peatlands actively function only in the spring and in the autumn with minimal evaporation during the summer. These features support stability of peatlands even in conditions of possible climate fluctuations.

The variation of thermodynamic variables in space at various hierarchical levels of the landscape organization allows allocating types of elementary landscape units and their hierarchically coordinated complexes on their relation and estimating corresponding spatial gradients. It is possible to believe, that scales of their spatial gradients determine features of their functioning.

The field measurements of a spatial variation of a air and a soil temperatures, a leaf-area index by means of the fisheye digital camera on transect (length of 7 km) with step of 20 m in August, November and January are carried out. There is reliable enough connection of spatial variation of these variables with remote sensing data and derivative thermodynamic variables. The combination of the remote information and field observations allowed interpolating results of the last on all territory and for various time of day and seasons of year. On the same basis it is possible to allocate in exergy balance the work connected with synthesis of a bio-productivity. Finally the combination of a complex of field and remote measurements should assist an understanding of the mechanism of interaction of a relief, soil, vegetation and an atmosphere at various hierarchical levels of the landscapes organization and to create a basis for development of model of mesoclimate shaping, as a result of landscapes functioning.

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References

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