Mathematical modeling of surface fire initiation and spread

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The problems of wildfire initiation and spread was carried out in this paper. A mathematical model has been developed that describes the processes of heat and mass transfer in the surface layer of the atmosphere and in the forest zone, taking into account their mutual influence. Within the limits of the earlier applied models overterrestrial layer of atmosphere and the combustion front are considered as separate components or otherwise approximate relationships are used for description of their interaction [1]. It doesn't allow to describe nonstationary phenomena proceeding in the environment in a concrete way. The surface layer of forest is considered as a homogeneous two temperature, reacting, non - deformed medium. Temperatures of condensed (solid) and gaseous phases are separated out. The first includes a dry organic substance, moisture (water in the liquid-drop state), condensed pyrolysis and combustion products (coke, ash), mineral part of forest fuels components. In the gaseous phase we separate out only the components necessary to describe reactions of combustion (oxygen, combustible products of pyrolysis of forest fuels and the rest inert components). The solid phase constituting forest fuels has no intrinsic velocity, and its volumetric fractions, as compared to the gaseous phase, can be neglected in appropriate equations. It is considered that 1) the flow has a developed turbulent nature, molecular transfer being neglected, 2) gaseous phase density doesn't depend on the pressure because of the low velocities of the flow in comparison with the velocity of the sound, 3) forest canopy is supposed to be non-deformed porous medium. To describe the transfer of energy by radiation we use a diffusion approximation, while to describe convective transfer controlled by the wind and gravity, we use Reynolds equations for turbulent flow. The research is done by means of mathematical modeling of physical processes. It is based on numerical solution of three - dimensional Reynolds equations for chemical components and equations of energy conservation for gaseous and condensed (for canopy) phases. The boundary-value problem is solved numerically using the method of splitting according to physical processes. In the first stage, the hydrodynamic pattern of flow and distribution of scalar functions are calculated. The system of ordinary differential equations of chemical kinetics obtained as a result of splitting are then integrated. A discrete analog for equations is obtained by means of the finite volume method using the SIMPLE algorithm. As a result of mathematical modeling the fields of temperatures, mass concentrations of components of gaseous phase, volume fractions of components of solid phase, as well as vectoral fields of velocity at different instants of time with taking into account mutual influence of the overterrestrial layer of atmosphere and a crown fire on each other will be obtained. It allows to investigate dynamics of surface fire initiation and spread under influence of various external conditions: a) meteorology conditions (air temperature, wind velocity etc.), b) terrain, c) type(various kinds of forest combustible materials) and their state(load, moisture etc.). A great deal of final and intermediate gaseous and dispersed combustion products of forest fuels is known to be exhausted into the atmosphere during fires: carbon monoxide, carbon dioxide, nitrogen oxide, soot, smoke, methane, other hydrocarbons and etc.

References

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