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Satellite Data Oriented Land Surface Model for Cold Regions: development and application for simulation of water and heat balance components in a vast agricultural terrain

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Satellite Data Oriented Land Surface Model for Cold Regions (SDOLSM_CR) utilizing land surface and snow cover characteristics derived from satellite data has been developed to simulate water and heat balance components for terrain of a regional scale. The model applicability has been demonstrated for the 227,000 sq.km agricultural region located in the European part of Russia. The SDOLSM_CR is the system of models containing physically based distributed models of hydrothermal processes in soil, vegetation and snow cover during both warm and cold seasons of a year. The models are based mostly on the partial differential equations describing processes of snow accumulation and melt, multiphase water and heat transfer in soil during its freezing and thawing, as well as in vegetation season, evapotranspiration and soil moisture dynamics. To assign the model parameters, being mostly measurable characteristics of soil, vegetation and snow cover, as well as to calibrate and validate the model, we have used t first ground-based observation data at agricultural meteorological stations for 1971-2010. Then, in order to provide for appropriate spatial reproduction of the simulated hydrological processes, we have utilized (as the model parameters or input variables) satellite-derived estimates of land surface and snow cover characteristics built from multispectral measurements of AVHRR/NOAA (1999-2010), MODIS/EOS Terra & Aqua (2002-2010), AMSR-E/Aqua (2003-2004; 2009-2010), and SEVIRI/Meteosat -8, -9 (2009-2010). New technologies of the satellite data thematic processing have been developed and applied to estimate land surface characteristics, such as surface skin brightness temperature, air foliage temperature, efficient land surface temperature and emissivity, normalized vegetation index, vegetation cover fraction and leaf area index, snow water equivalent and snow covered area, etc. Effective assimilation of the listed satellite products in the SDOLSM_CR has been provided, for example, utilizing satellite-based estimates of leaf area index and vegetation cover fraction as the model parameters instead of their ground-based values; using satellite-derived land surface temperatures as the input variables in place of the ground-measured ones and assessment of their influence on simulation results; using satellite data on snow cover fraction for improving calibration of snow model and better reproduction of spatial snow patterns during a melt period. It has been shown that the utilization of satellite information in the SDOLSM_CR allows reproducing spatial fields of snow characteristics, evapotranspiration, soil moisture and temperature at different soil depths, turbulent fluxes, temperature of soil/vegetation surfaces and other hydrothermal characteristics for the vast agricultural terrain, especially under the lack of ground observation data.
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