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Utilization of satellite data for modeling water and heat regimes of vast agricultural area over vegetation season

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The method to assess elements of water and heat regimes of vast agricultural region over the vegetation season was developed. It bases on the physical-mathematical model of water and heat exchange between land surface and atmosphere adapted to satellite-derived estimates of vegetation and meteorological characteristics. The model is intended to calculate soil water content W, evapotranspiration Ev, vertical heat fluxes and other water and heat regime characteristics, as well as distribution of soil moisture and temperature in depth and soil surface moisture and temperature. Soil and vegetation characteristics were considered to be model parameters and meteorological characteristics were used as input variables. Satellite data from radiometers AVHRR/NOAA, SEVIRI/Meteosat-10, -11 and MSU-MR/Meteor-M No 2 were used to retrieve estimates of leaf area index LAI, vegetation cover fraction B, precipitation and land surface temperature LST. The case study was carried out for the located in the forest-steppe zone part of the Central Black Earth region of European Russia of 227300 km2 for 2016-2017 vegetation seasons.

Estimates of B and LAI were obtained using empirical dependencies on vegetation index NDVI and emissivity E. The adequacy of such estimates was verified by comparing the LAI behaviors during vegetation season built from ground-based measurements and from data of all sensors. The errors of determining B and LAI were, correspondingly, about 10 and 15%.

Satellite-derived estimates of daily, decadal and monthly precipitation sums were obtained using the Multi Threshold Method (MTM) to detect clouds, identify its types, allocate precipitation zones and determine maximum precipitation intensities. Precipitation amounts were calculated using regression equations, where AVHRR-, SEVIRI- and MSU-MR-measured data in several channels and their differences were used as predictors. The correctness of such satellite-derived estimates of precipitation was confirmed by comparing with each other and with results of measurements at meteorological stations. For the region under study coincidence of satellite-detected precipitation zones with ground-observed ones was 75-85 %.

Satellite-based estimates of LST were built using the computational algorithm developed on the basis of the MTM and tested for the region of interest. The differences of the satellite-derived and ground-measured values of LST did not exceed RMSE of its determining from AVHRR data taken as reference.

The desired water and heat regime characteristics were calculated when assimilating described satellite estimates into the model by entering their values in each node of computational grid at each time step. Values of W and Ev modeled for all variants of B, LAI, precipitation and LST estimation were compared with observed ones. RMSE of these calculations were 10-15 % for W and 20-25 % for Ev. It can be considered an acceptable result.

Results of calculating soil surface moisture using measurement data from scatterometer ASCAT/MetOp-B in microwave range were also shown. These results were used to set the initial soil moisture profile and estimate evaporation from soil surface when calculating the value of W.

The described method of assessing the water and heat regime characteristics can be especially demanded for areas with rare network of ground-based observations or in their absence.