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Utilization of satellite-derived estimates of meteorological and land surface characteristics in the Land Surface Model for vast agricultural region territory

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The method has been elaborated to evaluate the water and heat regime characteristics of the territory on a regional scale for the vegetation season based on a physical-mathematical model of water and heat exchange between vegetation covered land surface and atmosphere (LSM, Land Surface Model) appropriate for using satellite information on land surface and meteorological conditions. The developed model is intended for calculating soil water content, evapotranspiration (evaporation from bare soil and transpiration by vegetation), vertical water and heat fluxes as well as land surface and vegetation cover temperatures and vertical distributions of temperature and moisture in the active soil layer. Parameters of the model are soil and vegetation characteristics and input variables are meteorological characteristics. Their values have been obtained from ground-based observations at agricultural meteorological stations and satellite-based measurements by scanning radiometers AVHRR/NOAA, MODIS/EOS Terra and Aqua and SEVIRI (geostationary satellites Meteosat-9, -10). The AVHRR data have been used to build the estimates of three types of land surface temperature (LST): land skin temperature Tsg, air temperature at a level of vegetation cover Ta and efficient radiation temperature Tseff, emissivity E, normalized vegetation index NDVI, vegetation cover fraction B, leaf area index LAI, and precipitation. The set of estimates derived from MODIS data has comprised values of LST Tls, E, NDVI and LAI. The SEVIRI-based retrievals have included Tls, Ta, at daylight and nighttime, LAI (daily) and precipitation.

The case study has been carried out for agricultural Central Black Earth region of the European Russia of 227,300 sq.km containing 7 regions of the Russian Federation for years 2009-2013 vegetation seasons.

Estimates of described characteristics have been built with the help of the developed original and improved pre-existing methods and technologies of thematic processing data from named radiometers. All technologies have been adapted to the study area. Verification of the AVHRR- and MODIS-derived LST estimates has been performed through comparison with ground-measured temperatures and analogous estimates obtained from remaining sensors. The reliability of SEVIRI-derived LST estimates has been verified by comparison with similar synchronous SEVIRI-derived estimates produced in LSA SAF (Land Surface Analysis Satellite Applications Facility, Lisbon, Portugal). Correctness of LAI estimates has been confirmed by comparing time behavior of satellite- and ground-based LAI during vegetation season.

Satellite-derived estimates of precipitation have been built using the Multi Threshold Method (MTM) developed for automatic pixel-by-pixel classification of AVHRR and SEVIRI data. The method is intended for the cloud detection and identification of its types, estimation of the maximum liquid water content and water content of the cloud layer, allocation of precipitation zones and determination of instantaneous maximum intensities of precipitation in the pixel range around the clock throughout the year independently of the land surface type. Measurement data from five AVHRR channels or from eleven SEVIRI channels as well as their differences have been used in the MTM as predictors. To validate the methodology, ground-based observation data on daily precipitation sums at agricultural meteorological stations of the study region have been used. The probability of correct precipitation zone detection from satellite data is at least 70% (80–85% in some cases) when compared with ground-based observations. In the frame of this approach the transition from the rainfall intensity estimation to the calculation of their daily values has been accomplished. In the study the AVHRR- and SEVIRI-derived daily, monthly and annual sums of precipitation for the region of interest have been calculated. The daily and monthly sums have been found to be in good agreement with each other and with ground-measured values although they have been smoother than the latter ones. Discrepancies have been recognized only for local maxima for which satellite-derived precipitation estimates have been considerably less than for the ground-based ones. This may be due to different scales of pixel-averaged satellite-derived and point-wise ground-based estimates.

Estimates of the all above characteristics have been obtained in the form of area distributions over the study territory.

Assimilation of satellite-based estimates of the meteorological and vegetation characteristics in the model has been carried out by replacing the values of precipitation, LST, LAI and B determined from observations at agricultural meteorological stations by their satellite-derived values taking into account space heterogeneity of their fields. Adequacy of such replacement has been confirmed by the results of comparing ground-measured and modeled values of evapotranspiration Ev and soil moisture content W.
Simulated by the adapted to satellite data LS-model spatial fields of evapotranspiration, soil water and heat content, vertical sensible and latent heat fluxes and other water and heat regime characteristics of the territory under consideration are the final result of the study. All model calculations have been carried out for years 2009-2013 vegetation seasons. Discrepancies between the modeled and ground-measured values of Ev and W does not exceeded 25 and 15 % that is acceptable result.