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Utilizing remote sensing data for modeling water and heat regimes of the Black Earth Region territory of the European Russia

Eugene Muzylev (1), Zoya Startseva (1), Alexander Uspensky (2), Elena Volkova (2), and Sergey Uspensky (2)

(1) Water Problem Institute of Russian Academy of Sciences, Moscow, Russian Federation (muzylev@aqua.laser.ru, 7-499-1355403), (2) State Research Center of Space Hydrometeorology Planeta, Moscow, Russian Federation (uspensky@planet.iitp.ru, 7-499-7952407)

At present physical-mathematical modeling processes of water and heat exchange between vegetation covered land surfaces and atmosphere is the most appropriate method to describe peculiarities of water and heat regime formation for large territories. The developed model of such processes (Land Surface Model, LSM) is intended for calculation evaporation, transpiration by vegetation, soil water content and other water and heat regime characteristics, as well as distributions of the soil temperature and humidity in depth utilizing remote sensing data from satellites on land surface and meteorological conditions. The model parameters and input variables are the soil and vegetation characteristics and the meteorological characteristics, correspondingly. Their values have been determined from ground-based observations or satellite-based measurements by radiometers AVHRR/NOAA, MODIS/EOS Terra and Aqua, SEVIRI/Meteosat-9, -10. The case study has been carried out for the part of the agricultural Central Black Earth region with coordinates 49.5 deg. - 54 deg. N, 31 deg. - 43 deg. E and a total area of 227,300 km2 located in the steppe-forest zone of the European Russia for years 2009-2012 vegetation seasons.
From AVHRR data there have been derived the estimates of three types of land surface temperature (LST): land surface skin temperature Tsg, air-foliage temperature Ta and efficient radiation temperature Ts.eff, emissivity E, normalized vegetation index NDVI, vegetation cover fraction B, leaf area index LAI, cloudiness and precipitation. From MODIS data the estimates of LST Tls, E, NDVI and LAI have been obtained. The SEVIRI data have been used to build the estimates of Tls, Ta, E, LAI and precipitation.
Previously developed method and technology of above AVHRR-derived estimates have been improved and adapted to the study area. To check the reliability of the Ts.eff and Ta estimations for named seasons the error statistics of their definitions has been analyzed through comparison with data of observations at agricultural meteorological stations of the study region. The mentioned MODIS-based remote sensing products for the same vegetation seasons have been built using data downloaded from the website LP DAAC (NASA). Reliability of the MODIS-derived Tls estimates have been confirmed by results of comparison with similar estimates from synchronous AVHRR, SEVIRI and ground-based data.
To retrieve Tls and E from SEVIRI data at daylight and nighttime there have been developed the method and technology of thematic processing these data in IR channels NN 9, 10 (10.8 and 12.0 nm) at three successive times under cloud-free conditions without using exact values of E. This technology has been also adapted to the study area. Analysis of reliability of Tls estimation have been carried out through comparing with synchronous SEVIRI-derived Tls estimates obtained at Land Surface Analysis Satellite Applications Facility (LSA SAF, Lisbon, Portugal) and MODIS-derived Tls estimates. When the first comparison daily - or monthly-averaged values of RMS deviation have not been exceeded 2 deg. C for various dates and months during years 2009-2012 vegetation seasons. RMS deviation of Tls(SEVIRI) from Tls(MODIS) has been in the range of 1.0-3.0 deg. C. The method and technology have been also developed and tested to define Ta values from SEVIRI data at daylight and nighttime. This method is based on using satellite-derived estimates of Tls and regression relationship between Tls and ground-measured values of Ta. Comparison of satellite-based Ta estimates with data of synchronous standard term ground-based observations at the network of meteorological stations of the study area for summer periods of 2009-2012 has given RMS deviation values in the range of 1.8-3.0 deg. C. Formed archive of satellite products has been also supplemented with array of LAI estimates retrieved from SEVIRI data at LSA SAF for the study area and growing seasons 2011-2012.
The possibility is shown to use the developed Multi Threshold Method (MTM) for generating the AVHRR- and SEVIRI-based estimates of daily and monthly precipitation amounts for the region of interest The MTM provides the cloud detection and identification of cloud types, estimation of the maximum liquid water content and cloud layer water content, allocation of precipitation zones and determination of instantaneous maximum of precipitation intensities in the pixel range around the clock throughout the year independently of the land surface type. In

developing procedures of utilizing satellite estimates of precipitation during the vegetation season in the model there have been built up algorithms and programs of transition from estimating the rainfall intensity to assessment of their daily values. The comparison of the daily, monthly and seasonal AVHRR- and SEVIRI-derived precipitation sums with similar values retrieved from network ground-based observations using weighting interpolation procedure have been carried out. Agreement of all three evaluations is satisfactory.

To assimilate remote sensing products into the model the special techniques have been developed including: 1) replacement of ground-measured model parameters LAI and B by their satellite-derived estimates. The possibility of such replacement has been confirmed through various comparisons of: a) LAI behavior for ground- and satellite-derived values; b) modeled values of Ts and Tf , satellite-based estimates of Ts.eff, Tls and Ta and ground-based measurements of LST; c) modeled and measured values of soil water content W and evapotranspiration Ev; 2) utilization of satellite-derived values of LSTs Ts.eff, Tls and Ta, and estimates of precipitation as the input model variables instead of the respective ground-measured temperatures and rainfall when assessing the accuracy of soil water content, evapotranspiration and soil temperature calculations; 3) accounting for the spatial variability of satellite-based LAI, B, LST and precipitation estimates by entering their area-distributed values into the model.

For years 2009-2012 vegetation seasons there have been calculated the characteristics of the water and heat regimes of the region under investigation utilizing satellite estimates of vegetation characteristics, LST and precipitation in the model. The calculation results have shown that the discrepancies of evapotranspiration and soil water content values are within acceptable limits.