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Utilization of satellite remote sensing data on land surface characteristics in water and heat balance component modeling for vegetation covered territories

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The model of vertical water and heat transfer in the "soil-vegetation-atmosphere" system (SVAT) for vegetation covered territory has been developed, allowing assimilating satellite remote sensing data on land surface condition as well as accounting for heterogeneities of vegetation and meteorological characteristics. The model provides the calculation of water and heat balance components (such as evapotranspiration Ev, soil water content W, sensible and latent heat fluxes and others) as well as vertical soil moisture and temperature distributions, temperatures of soil surface and foliage, land surface brightness temperature for any time interval within vegetation season. To describe the landscape diversity soil constants and leaf area index LAI, vegetation cover fraction B, and other vegetation characteristics are used. All these values are considered to be the model parameters. Territory of Kursk region with square about 15 thousands km2 situated in the Black Earth zone of Central Russia was chosen for investigation.

Satellite-derived estimates of land surface characteristics have been constructed under cloud-free condition basing AVHRR/NOAA, MODIS/EOS Terra and EOS Aqua, SEVIRI/Meteosat-8, -9 data. The developed technologies of AVHRR data thematic processing have been refined providing the retrieval of surface skin brightness temperature Tsg, air foliage temperature Ta, efficient surface temperature Ts.eff and emissivity E, as well as derivation of vegetation index NDVI, B, and LAI. The linear regression estimators for Tsg, Ta and LAI have been built using representative training samples for 2003-2009 vegetation seasons. The updated software package has been applied for AVHRR data thematic processing to generate named remote sensing products for various dates of the above vegetation seasons. The error statistics of Ta, Ts.eff and sg derivation has been investigated for various samples using comparison with in-situ measurements that has given RMS errors in the range 2.0-2.6, 2.5-3.7, and 3.5-4.9°C respectively.

The dataset of remote sensing products has been compiled on the base of special technology using Internet resources, that includes MODIS-based estimates of land surface temperature (LST) Tsg, E, NDVI, LAI for the region of interest and the same vegetation seasons. Two types of MODIS-based sg and E estimates have been extracted from LP DAAC web-site (for separate dates of 2003-2009 time period): LST/E Daily L3 product (MOD111) with spatial resolution $\sim$ 4.8 km and LST/E 5-Min L2 product (MOD11_L2) with spatial resolution $\sim$ 1 km. The verification of Tsg estimates has been performed via comparison with analogous and collocated AVHRR-based ones.

Along with this the sample of SEVIRI-based Tsg and E estimates has been accumulated for the Kursk area and surrounding territories for the time interval of several days during 2009 vegetation season. To retrieve sg and from SEVIRI/Meteosat-8, -9 data the new method has been developed. Being designed as the combination of well-known Split Window Technique and Two Temperature Method algorithms it provides the derivation of sg from SEVIRI/Meteosat-9 measurements carried out at three successive times (classified as 100% cloud-free) and covering the region under consideration without accurate a priory knowledge of E. Comparison of the SEVIRI-based Tsg retrievals with the independent collocated Tsg estimates gives the values of RMS deviation in the range of 0.9-1.4°C and it proves (indirectly) the efficiency of proposed approach.

To assimilate satellite-derived estimates of vegetation characteristics and LST in the SVAT model some procedures have been developed. These procedures have included:

1) the replacement of LAI and B ground and point-wise estimates by their AVHRR- or MODIS-based analogues. The efficiency of such approach has been proved through comparison between satellite-derived and ground-based seasonal time behaviors of LAI and B, between satellite-derived, modeled, and in-situ measured temperatures as well as through comparison the modeled and actual values of evapotranspiration Ev and soil water content W for one meter soil layer. The discrepancies between mentioned temperatures do not exceed the RMS errors of satellite-derived estimates Ta, Ts.eff and Tsg while the modeled and measured values of Ev and W have been found close to each other within their standard estimation error;

2) the treating AVHRR- or MODIS-based LST as the input model variable within the SVAT model instead their standard ground-based estimates if the satisfactory time-matching of satellite and ground-based observations takes place. The SEVIRI-derived Tsg can be also used for these aims. Permissibility of such replacement has been verified while comparing remote sensed, modeled and ground-based temperatures as well as calculated and measured values of W and Ev. The SEVIRI-based Tsg estimates were found to be very informative and useful due to their high temporal resolution.

Moreover the approach has been developed to account for space variability of vegetation cover parameters and meteorological characteristics. This approach includes the development of algorithms and programs for entering AVHRR- and MODIS-derived LAI and B, all named satellite-based LSTs as well as ground-based precipitation, air temperature and humidity data prepared by Inverse Distance Weighted Average Method into the model in each calculation grid unit.

The calculations of vertical water and heat fluxes, soil water and heat contents and other water and heat balance components for Kursk region have been carried out with the help of the SVAT model using fields of AVHRR/3- and MODIS-derived LAI and B and AVHRR/3-, MODIS, and SEVIRI-derived LST for various vegetation seasons of 2003-2009. The acceptable accuracy levels of above values assessment have been achieved under all scenarios of parameter and input model variable specification. Thus, the results of this study confirm the opportunity of using area distributed satellite-derived estimates of land surface characteristics for the model calculations of water and heat balance components for large territories especially under the lack of ground observation data.

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