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Using satellite data on meteorological and vegetation characteristics and soil surface humidity in the Land Surface Model for the vast territory of agricultural destination

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The model of water and heat exchange between vegetation covered territory and atmosphere (LSM, Land Surface Model) for vegetation season has been developed to calculate soil water content, evapotranspiration, infiltration of water into the soil, vertical latent and sensible heat fluxes and other water and heat balances components as well as soil surface and vegetation cover temperatures and depth distributions of moisture and temperature. The LSM is suited for utilizing satellite-derived estimates of precipitation, land surface temperature and vegetation characteristics and soil surface humidity for each pixel. Vegetation and meteorological characteristics being the model parameters and input variables, correspondingly, have been estimated by ground observations and thematic processing measurement data of scanning radiometers AVHRR/NOAA, SEVIRI/Meteosat-9, -10 (MSG-2, -3) and MSU-MR/Meteor-M № 2. Values of soil surface humidity has been calculated from remote sensing data of scatterometers ASCAT/MetOp-A, -B. The case study has been carried out for the territory of part of the agricultural Central Black Earth Region of European Russia with area of 227300 km2 located in the forest-steppe zone for years 2012-2015 vegetation seasons.

The main objectives of the study have been:

- to built estimates of precipitation, land surface temperatures (LST) and vegetation characteristics from MSU-MR measurement data using the refined technologies (including algorithms and programs) of thematic processing satellite information matured on AVHRR and SEVIRI data. All technologies have been adapted to the area of interest;
- to investigate the possibility of utilizing satellite-derived estimates of values above in the LSM including verification of obtained estimates and development of procedure of their inputting into the model.

From the AVHRR data there have been built the estimates of precipitation, three types of LST: land skin temperature sg, air temperature at a level of vegetation cover (taken for vegetation temperature) Ta and efficient radiation temperature Ts.eff, as well as land surface emissivity E, normalized difference vegetation index NDVI, vegetation cover fraction B, and leaf area index LAI. The SEVIRI-based retrievals have included precipitation, LST ls and Ta, at daylight and nighttime, LAI (daily), and B. From the MSU-MR data there have been retrieved values of all the same characteristics as from the AVHRR data.

The MSU-MR-based daily and monthly sums of precipitation have been calculated using the developed earlier and modified Multi Threshold Method (MTM) intended for the cloud detection and identification of its types around the clock as well as allocation of precipitation zones and determination of instantaneous maximum rainfall intensities for each pixel at that the transition from assessing rainfall intensity to estimating their daily values is a key element of the MTM. Measurement data from 3 IR MSU-MR channels (3.8, 11 12 μm) as well as their differences have been used in the MTM as predictors. Controlling the correctness of the MSU-MR-derived rainfall estimates has been carried out when comparing with analogous AVHRR- and SEVIRI-based retrievals and with precipitation amounts measured at the agricultural meteorological station of the study region. Probability of rainfall zones determination from the MSU-MR data, to match against the actual ones, has been 75-85% as well as for the AVHRR and SEVIRI data. The time behaviors of satellite-derived and ground-measured daily and monthly precipitation sums for vegetation season and year¸ correspondingly, have been in good agreement with each other although the first ones have been smoother than the latter. Discrepancies have existed for a number of local maxima for which satellite-derived precipitation estimates have been less than ground-measured values. It may be due to the different spatial scales of areal satellite-derived and point ground-based estimates. Some spatial displacement of the satellite-determined rainfall maxima and minima regarding to ground-based data can be explained by the discrepancy between the cloud location on satellite images and in reality at high angles of the satellite sightings and considerable altitudes of the cloud tops. Reliability of MSU-MR-derived rainfall estimates at each time step obtained using the MTM has been verified by comparing their values determined from the MSU-MR, AVHRR and SEVIRI measurements and distributed over the study area with similar estimates obtained by interpolation of ground observation data.

The MSU-MR-derived estimates of temperatures Tsg, s.eff, and have been obtained using computational algorithm developed on the base of the MTM and matured on AVHRR and SEVIRI data for the region under investigation. Since the apparatus MSU-MR is similar to radiometer AVHRR, the developed methods of satellite estimating Tsg, s.eff, and from AVHRR data could be easily transferred to the MSU-MR data. Comparison of the ground-measured and MSU-MR-, AVHRR- and SEVIRI-derived LSTs has shown that the differences between all the estimates for the vast majority of observation terms have not exceed the RMSE of these quantities built from the AVHRR data. The similar conclusion has been also made from the results of building the time behavior of the MSU-MR-derived value of LAI for vegetation season.

Satellite-based estimates of precipitation, LST, LAI and B have been utilized in the model with the help of specially developed procedures of replacing these values determined from observations at agricultural meteorological stations by their satellite-derived values taking into account spatial heterogeneity of their fields. Adequacy of such replacement has been confirmed by the results of comparing modeled and ground-measured values of soil moisture content W and evapotranspiration Ev. Discrepancies between the modeled and ground-measured values of W and Ev have been in the range of 10-15 and 20-25 %, correspondingly. It may be considered as acceptable result.

Resulted products of the model calculations using satellite data have been spatial fields of W, Ev, vertical sensible and latent heat fluxes and other water and heat regime characteristics for the region of interest over the year 2012-2015 vegetation seasons. Thus, there has been shown the possibility of utilizing MSU-MR/Meteor-M №2 data jointly with those of other satellites in the LSM to calculate characteristics of water and heat regimes for the area under consideration.

Besides the first trial estimations of the soil surface moisture from ASCAT scatterometers data for the study region have been obtained for the years 2014-2015 vegetation seasons, their comparison has been performed with the results of modeling for several agricultural meteorological stations of the region that has been carried out utilizing ground-based and satellite data, specific requirements for the obtained information have been formulated. To date, estimates of surface moisture built from ASCAT data can be used for the selection of the model soil parameter values and the initial soil moisture conditions for the vegetation season.