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Utilization of multispectral satellite data on land surface and snow characteristics for modeling water and heat balance components in a vast agricultural terrain

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The technologies of thematic processing satellite data on land surface and snow characteristics as well as the methods of utilizing the processed data in the Satellite Data Oriented Land Surface Model for Cold Regions (SDOLSM_CR) for simulating water and heat balance components in a vast agricultural terrain are presented. The case study has been carried out for the 227,000 sq.km agricultural region located in the European part of Russia. Satellite-derived estimates of land surface and snow cover characteristics built from multispectral measurements of AVHRR/NOAA (1999-2010), MODIS/EOS Terra & Aqua (2002-2010), AMSR-E/Aqua (2003-2004; 2009-2010), and SEVIRI/Meteosat -8, -9 (2009-2010) have been used. Earlier developed technologies of AVHRR data processing have been refined and adapted to the region of interest to retrieve soil surface temperature Tsg and emissivity E, surface-air temperature (at a level of vegetation cover) Ta, effective radiant temperature Ts.eff (weighted linear combination of Ta and Tsg), normalized vegetation index NDVI, leaf area index LAI and vegetation cover fraction B. The linear regression estimators for Ts.eff, Tsg and Ta have been built using more representative samples of AVHRR data. Using this technology estimates of all named vegetation and meteorological characteristics have been generated for different dates of the above seasons. The error statistics of Ts.eff, Tsg and Ta estimation has been analyzed basing on their comparison with synchronous collocated in-situ measurements at agricultural meteorological stations of the region. On the base of special developed technology and Internet resources the remote sounding products (land surface temperature (LST) Tls, E, NDVI, LAI) derived from MODIS/EOS Terra & Aqua data and covering the territory under investigation have been downloaded from LP DAAC web-site for the same vegetation seasons. Estimates of named characteristics have been compiled with spatial resolution 4.8 km and 1 km. Comparison of MODIS-derived Tls estimates with similar quasi-synchronous AVHRR/3-derived ones and results of in-situ measurements has confirmed their reliability. The archive of synchronous AVHRR/NOAA and MODIS/EOS Terra & Aqua-based remote sensing products and in-situ hydro-meteorological observations has been complemented by the SEVIRI-derived Tls and E estimates for several 5-6 days time intervals during June-August 2009 and 2010 (at daylight and nighttime or only at daylight respectively). To retrieve these estimates from SEVIRI/Meteosat-8, -9 data the new technique has been developed. It represents the combination of well-known “Split Window” and “Two Temperature” algorithms and allows estimating Tls and E from SEVIRI measurements carried out at three successive times (for example, at 11.00, 12.00, 13.00 UTC or at 23.00, 24.00, 01.00 UTC) classified as 100% cloud-free and covering the region of interest without accurate a priory knowledge of E. Comparison of obtained SEVIRI-derived Tls estimates to analogous independent collocated Tls ones generated at LSA SAF(Lisbon, Portugal) gives daily - or monthly-averaged values of RMS deviation in the range of 0.8-1.6 K for various dates and months during June-August 2009. Such value of discrepancy can be considered as indirect confirmation of the proposed method efficiency. A new approach to combine MODIS and AMSR-E snow retrievals optimally and to generate continuous (gap-free) snow cover maps has been developed and tested. All historical MODIS and AMSR-E data since 2003 have been reprocessed, thus the derived snow map time series cover continuously the time period from 2003 to 2009.

To provide effective assimilation of described remotely sensed products in the SDOLSM_CR there have been developed some corresponding procedures: (1) replacing the ground-based estimates of LAI and B using as the model parameters by their satellite-based analogues, testing simulation results after this replacement by comparing the modeled values of LST with the satellite-derived ones, as well as the modeled values of soil moisture content and evapotranspiration with the corresponding observed values; (2) entering the AVHRR-, MODIS- and SEVIRI-derived values of LST Ts.eff (Tls) into the model as the input model variables instead of the corresponding ground-measured temperatures, assessment of the accuracy of modeling the soil moisture content,

soil temperature and evapotranspiration; (3) inputing areal distributions of LAI, B, and Ts.eff (Tls) retrieved from all aforementioned satellite data into the model as a way to integrate spatial variability of vegetation characteristics and land surface temperature in the model; (4) using satellite data on snow cover fraction for improving calibration of snow model and better reproduction of spatial snow patterns during a melt period. As a result of the developed procedures, adequate estimates of water and heat balance components (evapotranspiration, moisture and heat content at different soil layers, snow characteristics, etc.) have been obtained over the study area.

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