The CCM2 River and catchment dataset employed in Bulgarian hydrologic modeling investigations

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Abstract

The evaluation of the Bulgarian watersheds runoff and the groundwater recharge is necessary information basis for management of the water resources protection and usage. The assessment of the daily and monthly average soil moisture is made for different purposes and it is monitored on country scale. These hydrological assessments are prepared by the Community Land Model - CLM3. An important part of the software output is completed and visualized using the geographical information obtained from the free GIS - CCM2 River and catchment dataset. It makes possible the delineation of the watersheds and using the grid elements of the CLM3 model enables the computation of the catchments total runoff and groundwater recharge.

The report presents some precipitation-runoff calculations in Bulgaria carried out by the CLM3 model using the free available CCM2 dataset. They consist in assessment of:

- the recharge of the groundwater body Bellene, for checking the eventual necessity of abstraction limitations;
- the runoff from the Topolnitza reservoir watershed for assessment of the downstream flood hazard and
- the average monthly soil moisture anomaly or detection of drought, fire and flood conditions.

Keywords: land surface scheme (CLM), river network (CCM2), hydrological assessments.

1 Introduction

The preparation and presentation of the final results from different research studies needs integrated application of various software products. In the environmental investigations the GIS products are a basic instrument. It works with many types of file configurations and enables the output from the spatially distributed models to be visualized and processed for different purposes.

In the present study regarded are hydrologic assessments by virtue of the Land Surface Scheme (Community Land Model - CLM3) of the Global Climate Model (NCAR Community Climate Model – CCSM3) [11]. This is a complex spatially distributed model, requiring detailed data base input and working in Linux operation system environment. The input/output data files, as to the last conventions for storage and operation with climatic data, are in netCDF format. The output data from the model are calculated and presented as averaged values of the cells with area according to the desired by the user spatial grid resolution (5 x 5 km in our case). It means that the model results as runoff, infiltration, evaporation or other elements of the energy balance of the soil surface are values attributed to the grid cells. For obtaining the total values of those elements within a confined part of the investigated domain, as a river watershed for example, it is necessary the summation of these values over its area. For the purpose the created intelligent hydrographic CCM2 River and Catchment data set [4], which is a GIS product, is used. This way the calculation of the Watershed runoff for instance is done in two steps. On the first step the spatially distributed runoff over an area containing the watershed is computed by the CLM3 model as grid cells average values. On the next step the task proceeds in GIS platform by integration of the cell values for obtaining the watershed total runoff or other hydrologic elements using the CCM2 data set and the Spatial Analyst tools. The free access into the JRC data base and the open source codes give an opportunity for all researchers and above all for the ones from the less developed countries to make use of the tool.

2 Application of the integrated CLM – CCM2 tool for Bulgaria

Community Land Model is the third (the highest) generation of the climate models. It is adopted and put into work after close examination and research studies by the author in the European Drought Observatory - the Institute for Environment and Sustainability (IES) of the European Commission in Italy and

Bulgarian Academy of Sciences in Bulgaria. So far in Bulgaria it has been applied with the land cover, soil and atmospheric forcing database of NASA. Atmospheric forcing input is with geographical mesh resolution 2º x 2º and time step discretization - 3 hours. Applied is near surface meteorological data, consisting in precipitation, air temperature, air pressure, specific humidity, shortwave and long wave radiation and wind speed values. That is the gridded data of NCEP/NCAR Reanalysis.

The CLM model contains rather precise sub models for the tree main water cycle processes: surface water runoff, infiltration and moisture transport through the soil profile, evaporation and evapotranspiration from the land surface. In the same time it has built-in all necessary input land surface information – topography, land cover, soil profiles texture and hydraulic properties, etc. The model resolution is rather large, which makes the model appropriate for more generalized, averaged assessments of the water cycle components – over large scale catchments and better for longer periods as months and years

In detailed research carried out earlier assessed are different model results [6, 8, 9]. They include runoff, infiltration and soil moisture. The computed by the model runoff was compared by the field observation for the watershed of Topolnitza river, a tributary of Maritza river [8]. The modelled values for the groundwater recharge were compared with naturally observed ones of the groundwater body Bellene, which waters directly outflow into Danube [6]. Comparison of the results from modelling and observations shows good enough performance of the Community Land Model for Bulgarian soil and Climate conditions.

2.1 Assessment of the "Topolnitza" reservoir inflow

The prediction of the reservoir inflow expected as a result of high forecast precipitations can be done on the base of calculated runoff from the river basin by means of different precipitation-runoff models. Such calculations serve the reservoir management especially when there are restrictions for high water discharges through their spillways.

In our case study the runoff is calculated by the CLM3 model. Parameterization of the runoff is based on the TOPMODEL, where introduced are a fractional saturated area and fractional unsaturated area. In a case of a saturated area the soil surface is saturated and precipitation that falls over that area runs off immediately and it is converted into surface runoff.

The CLM model was applied for the Topolnitza river subcatchment of the Maritza River watershed, just before the Topolnitza reservoir, with 1381 km^2 of the area. It is located in the North West part of the Maritza river basin. Maritza is the longest river that runs through the middle of the Balkans and flows into the Aegian Sea.

During the severe flood in August (03.08.-10.08.) 2005, the Maritza river created big problems – enormous losses and human death. It was the worst flooding in the past 70 years. Then the crucial point was the Topolnitza reservoir, when enormous water volumes flew downstream and destroyed large rural and urban areas [8].

Maritza River runs along the border between Greece and Turkey. There is an agreement between the three riparian countries for utilization and management of the shared water resources. Now collaboration is established for prevention and mitigation of Maritza river floods and their impact where the attention is paid for proper water management in the upper part of the river basin.

That is why the area of the Topolnitza reservoir catchment has been chosen for our study by the CLM model with the purpose of finding proper tool for assessment and forecast of high inflow in the Topolnitza reservoir.

Here considered is the model runoff for November 2013, given on Figure 1. By applying CCM2 hydrographic data sets for Bulgaria given on Figure 2, we were able to extract and calculate the monthly inflow in the Topolnitza reservoir equal to 12.8 mln m^3 shown on Figure 4. The reservoir inflow observations from 1970 – 2007 based on reservoir balance shows for November average inflow 10.1 mln m^3. The Bulgarian hydrologic bulletin for November 2013 gives 12% higher runoff for Maritza river basin compared to the multiannual observations. That proves the realism of the model estimation.

Figure 1: Calculated runoff for the territory of Bulgaria by the CLM model.

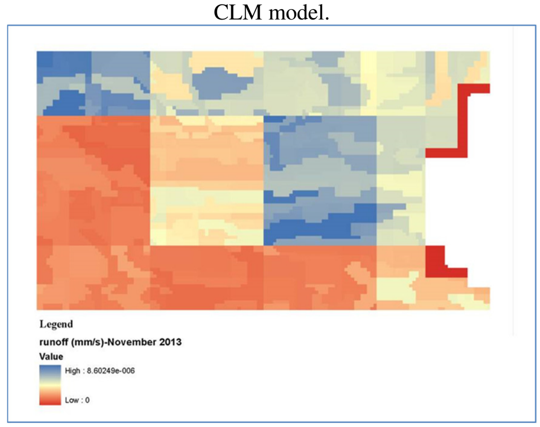
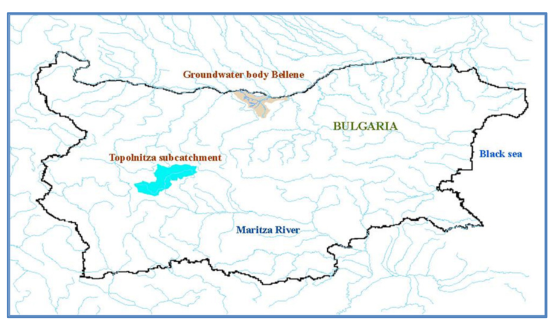


Figure 2: CCM2 River dataset and extracted watersheds of the groundwater body Bellene and Topolnitza subcatchment.



2.2 Assessment of the groundwater recharge of the groundwater body Bellene

The study was performed for the groundwater body Bellene which is considered as being in bad quantitative status – there is higher abstraction than the recharge. It is unconfined two layered groundwater body, with depth of 18 m. The first layer is clay-sand and the second layer is gravel-sand. The lower boundary situates at 20 m, bellow the ground surface. The groundwater body is fed by precipitations. In detailed research carried out earlier [6] by comparing the simulation recharge to the observation data it was shown the model reliability for groundwater recharge estimation.

Here reported are the results from the groundwater recharge assessment by the CLM3 model for the whole country territory (Figure 3) and the followed calculation by the CCM2 hydrographic data sets of the recharge from the groundwater body concrete catchment area. The result is shown on Figure 4. The mean monthly recharge for November 2003 is equal to 2200 l/s. The mean annual recharge of Bellene groundwater body on the basis of multiannual observations made by hydrodynamic method is 370 l/s in dry years and 670 l/s in wet years. The permitted abstraction is 490 l/s. The regarded period – November 2013 is characteristic with abundant precipitation which agrees with the obtained result for November.

Figure 3: Calculated groundwater recharge for the territory of Bulgaria by the CLM model.

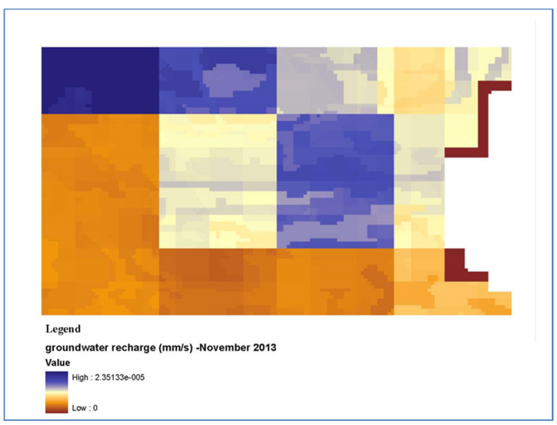
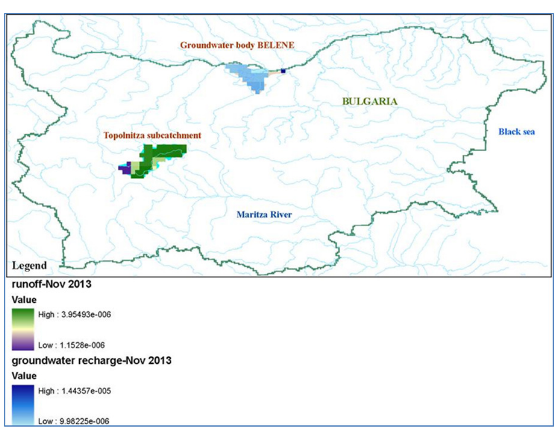


Figure 4: Integrated CLM model output and CCM2 River and catchment dataset for runoff and groundwater recharge calculations.



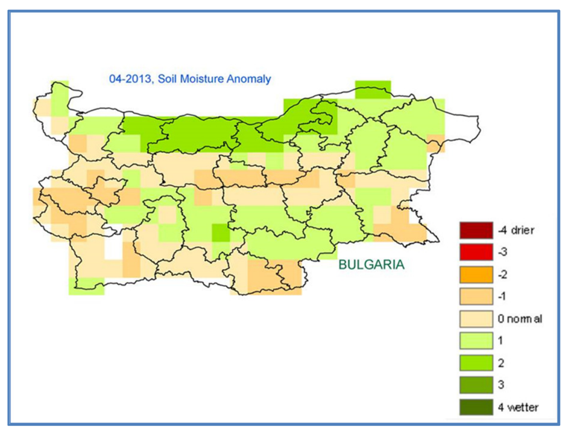
2.3 Monitoring the soil moisture anomalies in Bulgaria

The soil moisture information is an important characteristic not only for the agriculture and forest fire prevention, but it reflects as well the changes in the climatic conditions of the area [1, 2, 3, 7, 10]. A study of its variation during the last three decades with a statistical assessment of the deviation of its monthly values from the average one will give a good knowledge about the climatic processes taken place during that period. Special interest represents the observed moisture deviations greater than its standard value considered as anomalies [5]. Its values within the range (-1, 1) are assumed as normal for the considered month and region. They are considered as real anomalies when their values are outside of that range.

The proposed methodology [5] applied for the spring month of the 2013 shows that in North Central Bulgaria the soil moisture of the top soil layer are wetter than the average one (Figure 5). In the case the anomaly value reaches 2 (deviations 2 x σ) which means wet soil conditions and can be considered as first degree of anomaly.

The CCM2 administrative units division data set is used in visualization of the soil moisture anomaly results for quick and easy information of the involved in the problem authorities, experts and public.

Figure 5: Integrated CLM model results for soil moisture anomaly with the CCM2 dataset.



3 Conclusion

The main conclusion from the report is on one hand the applicability of the CLM3 model for important hydrologic assessments, serving the country waters management, and on the second hand the particular advantage in the regarded cases of the integrated usage of the model with the CCM2 river and catchment dataset tool for achievement of delineated areas hydrologic characteristics from the spatially distributed models computation data.

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