USE OF SHORT-RANGE WEATHER FORECAST MODEL ALADIN FOR THE MODELING OF THE SURFACE RUNOFF FOR THE MARITZA, TUNDJA & ARDA RIVER BASINS IN BULGARIA

Eram Artinyan, Andrey Bogachev, Valery Spiridonov
National Institute of Meteorology and Hydrology of Bulgaria
Eram.Artinian@meteo.bg; Andrey.Bogatchev@meteo.bg;
Valery.Spiridonov@meteo.bg

Abstract

This poster describes the testing of three coupled models for hydrologic modelling and forecast of large region of Republic of Bulgaria: the basins of Maritza, Tundja and Arda rivers. Aladin is a high definition, short-range NWP model extensively used in Europe. It receives boundary data from the French global model ARPEGE. A new forecast is produced each 12 hours, while the range of the forecast is 48 hours. The ISBA land surface scheme (Interface Soil – Biosphere – Atmosphere) describes the interactions between soil, biosphere and atmosphere in regional and climate models (Noilhan and Mahfouf, 1995). For the hydrological modelling, hydrological and hydro-geological distributed model MODCOU (Ledoux et al., 1989) is used. It simulates the spatial and temporal evolutions of water table, and of river flows. ISBA and MODCOU were coupled (Habets et al. 1999a, 1999b) in order to implement the surface scheme within a macroscale hydrological model at the regional scale.

In this case, the land surface scheme is forced by 2D outputs from the Aladin model collected for a period of 5 months. ISBA solves energy and water budgets, taking into account a vegetation cover. The resulting “free” water quantities are routed by the hydrological model, which represents the surface runoff in river cells. Finally, the hydrological model simulates the river flow up to the outlet of the basins.

In the realisation of this project are used precipitation data from meteorological stations, satellite data for the topography and vegetation (Champeaux et al., 1995), and data for the soils (Trendafilov, Kr., 1996). C. Golaz, Ecole des Mines de Paris, prepared surface river network and underground grid.

The comparison between the results of the modelling and the observations showed that for the south part of the region the short-range atmospheric model predicts fairly well the amount and location of the precipitations. According to that, the river flows are well represented by the hydrologic model. During the operation of ISBA land surface scheme, with Aladin precipitations, a correction of the soil moisture and snow pack by a surface scheme operating with a delay of one or two daily steps but using measured precipitations is performed. The effect of modification of the soil moisture and snow pack was tested with two time steps: 24 h and 48 h. The first is giving better statistical results when comparing the predicted and the measured streamflow.

Description of the region

The region under consideration takes one-third part of the territory of Bulgaria – 34000 km^2. It covers the central part of South Bulgaria, between the chain of Stara Planina Mountain and the borders with Greece and Turkey at the south (Figure 1). The climate is continental to Mediterranean in the valleys depending on the dominant atmospheric circulation. It has pronounced altitude variability as the elevation is going from 50 m up to 2925 m at the pick of Mussala in Rila Mountain.

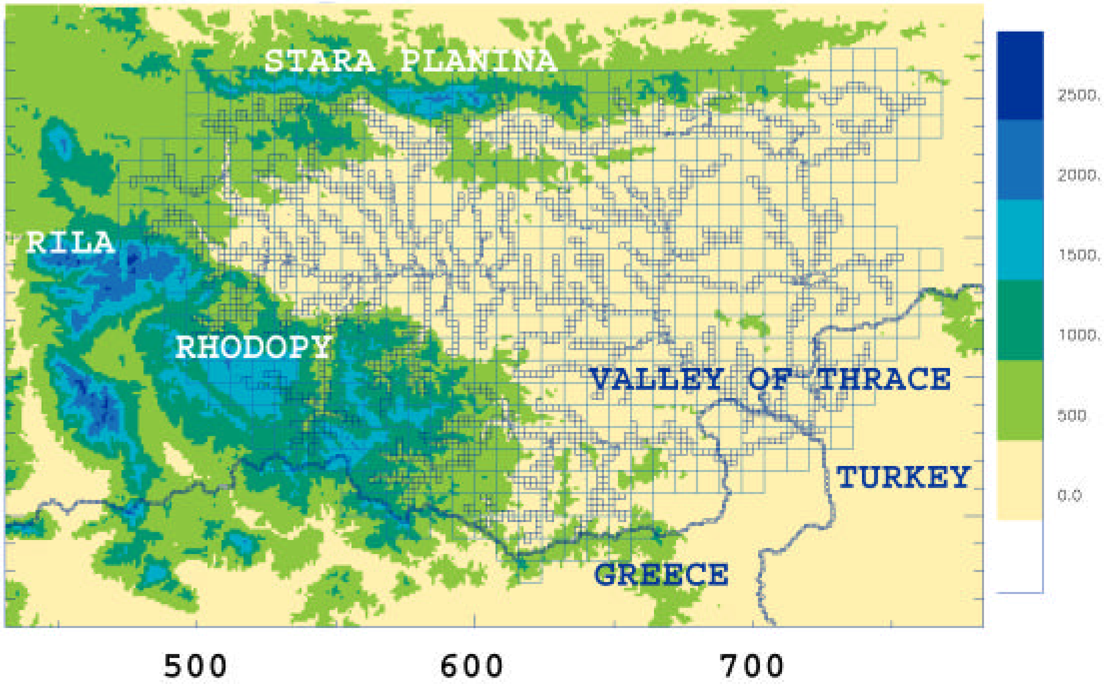


Figure 1: Map of the Maritza, Arda and Tundja River basins in Bulgaria

Objectives of the project

A. Real time monitoring of the water balance components

1. To provide real time diagnosis of the river flows over a large region of the country.
2. To evaluate the snow pack height and water content in real time
3. Soil moisture evaluation for hydrological and agronomical purposes

B. Short Range forecast of the river flows at predefined set of locations with a known degree of predictability.

1. One to two days forecast for the most endangered locations.
2. Short range prediction of the inflow of dams and ponds.

Actual state of the hydrologic modelling of the Maritza, Arda and Tundja watersheds

During the last years, an intensive research work was carried out, with a purpose to implement the coupled ISBA and MODCOU models. Because of the great variety and large amount of time independent data, for example vegetation types, soil properties and aquifers' storage and transmissivity, the preliminary period of models implementation and calibration was long. For the model calibration a set of routines was set up, in order to transform the available meteorological data from the NIMH (National Institute of Meteorology and Hydrology) network, from the point scale into high quality spatial fields with 3 h time step for a period of 26 months.

It was found out that without taking into account the human influence on the watershed, as dams' inflow and release, irrigation and other water uses, the hydrologic modelling was giving poor results and were not able to reproduce the river flows as they were measured at the gauging stations. These data were available at the NIMH only for a short period, as they were needed for the model calibration and tests. In the region under consideration, the dams are able to store up to $3x10^9$ m^3, which is roughly one half of the mean annual streamflow discharge. Apart from that, it was found out that in the mountain region a large part of the infiltrated water was retained in sub-surface structures, as fissured rocks and karstic areas, and released gradually few months after the last precipitation. This process was simulated with an additional module that slowed down the flow of a fraction of the drainage water.

The coupled models were calibrated for the hydrological year from October 95' to September 96' and validated for the next hydrological year. The results showed good fitting of simulated and measured streamflows for the not anthropogenized rivers. The computed evaporation was near to the measured values. The snow height variation and the relative soil moisture were well represented.

Short Description of the models used

A. Aladin (Aire Limitée Adaptation dynamique Développement InterNational)

High precision short range numerical weather prediction model

Aladin short-range NWP model has been operating at the NIMH since May 1999. The numerical weather prediction model ALADIN (http://www.cnrm.meteo.fr/aladin/) - has been used as operational model in Bulgaria since June 1999. The weather forecast for 48 hours over the Balkan Peninsula is computed twice a day using as initial conditions the predictions for 12 and 00 UTC of the French global model ARPEGE (Action de Recherche Petite Echelle Grande Echelle). The horizontal resolution of ALADIN is approximately 12 km, with 31 levels vertically. The model is widely used in Europe. It has three main implementations in Western Europe – France, Belgium, and Portugal, more than 7 in central and Eastern Europe and two in North Africa.

B. ISBA (Interface Soil Atmosphere Biosphere)

Land surface scheme

The ISBA surface scheme was developed for the climate, mesoscale and prediction atmospheric models used at Météo-France (http://www.cnrm.meteo.fr/mc2/). It aims to represent the main surface processes in a relatively simple way: it solves one energy budget for the soil and vegetation continuum, and uses the force-restore method (Deardorff, 1978) to compute energy and water transfers in the soil. Evapotranspiration is computed through four components: interception by the foliage, bare soil evaporation, transpiration of the vegetation (with a stress function computed using the method proposed by Jarvis (1976) and sublimation of the snowpack. Two fluxes of water in the soil are computed: a surface runoff (Qr) and drainage (D) (Figure 2)

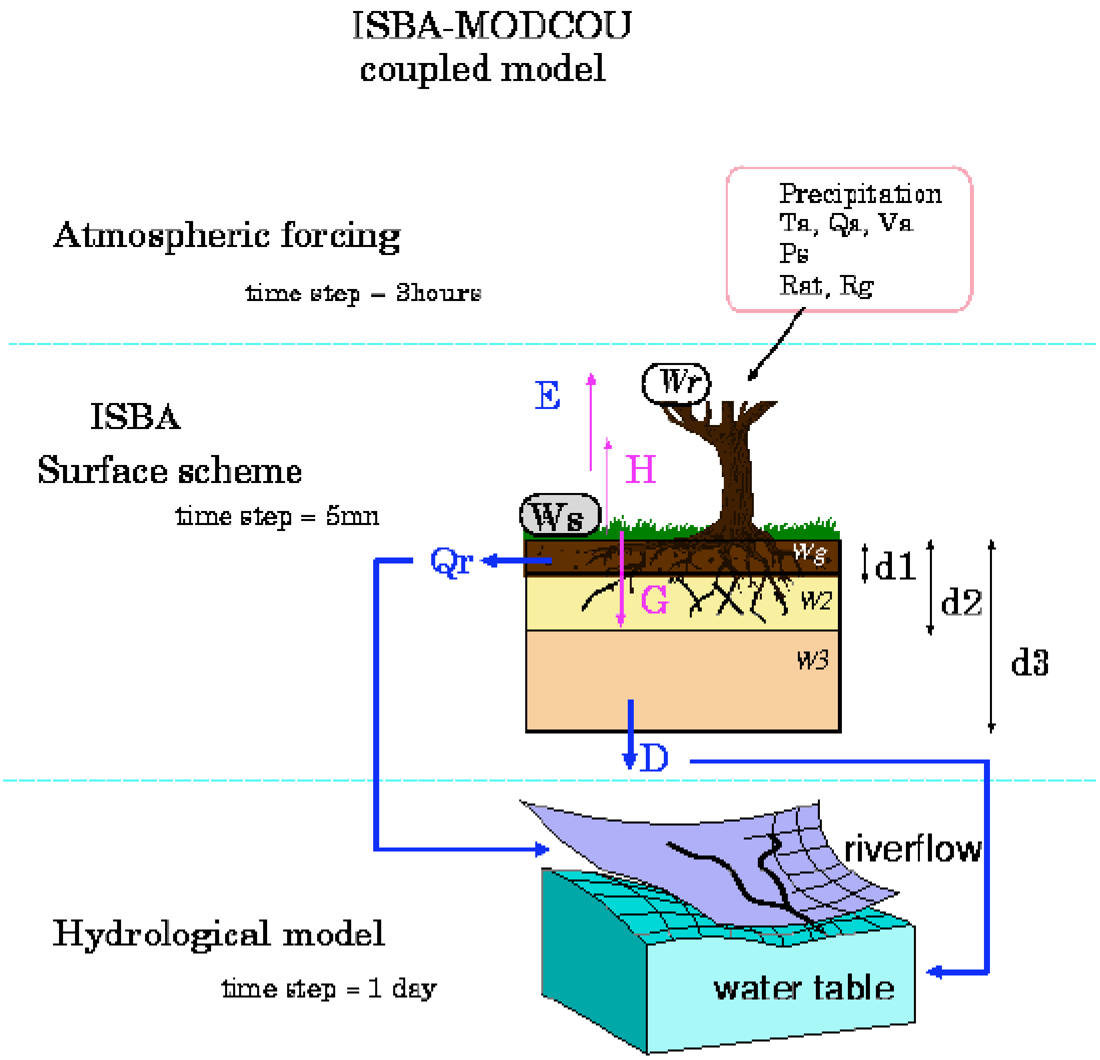


Figure 2: ISBA land surface scheme coupled with MODCOU macroscale hydrological model.

C. MODCOU

Distributed regional scale hydrological and hydro-geological model

The macro-scale hydrological model MODCOU was used in several applications (Ledoux et al., 1989; Ambroise et al., 1995; Violette et al., 1997). MODCOU takes into account a surface and the underground layers. The surface routing network is computed from the topography, using a geographical information system (Golaz, 1995). The surface and underground domains are divided into grid cells of size 1, 2, and 4 km. The transfer between two grid cells is estimated from the topography. The surface runoff computed by ISBA is routed to the river network (Figure 3) and then to the gauging stations using isochronous zones (Figure 4) with a daily time step. The drainage computed from ISBA contributes to the evolution of the groundwater table, which evolves according to the diffusivity equation. The exchanges of water between the groundwater table and the river are computed according to simple relations (Ledoux, 1980). At the end, the flows from the surface layer and from the groundwater table form the riverflow at the gauging stations.

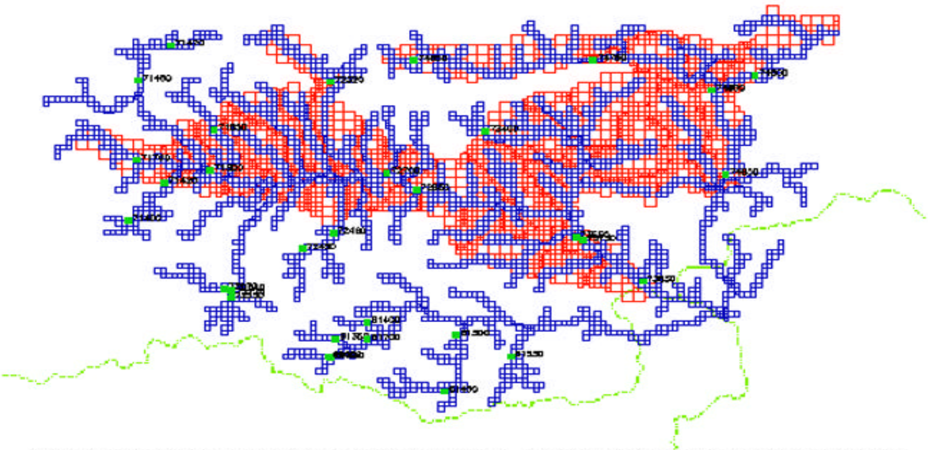


Figure 3 : River network (blue) and underground grid (red). Gauging stations are shown with green squares

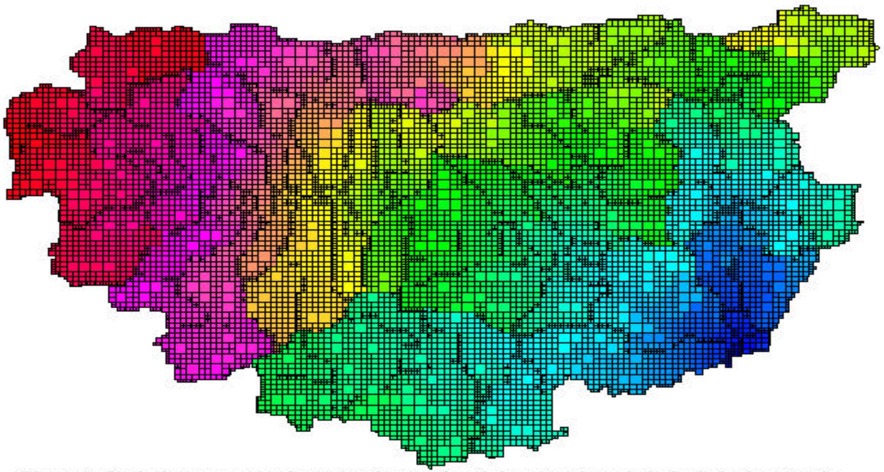


Figure 4 : Six izohronous zones determine the transfer of the water through the hydrologic network

Achieved project stages

A. Analysis of the project feasibility

Comparison of point scale temperature data of a synoptic station to the nearest Aladin grid point value: This analysis showed good approximation of the surface air temperature when using valley stations and less good quality of the simulation for the mountain stations. The reason could be the large difference between the average grid mesh altitude and the real elevation at the station location (Figure 5).

Comparison of the point scale temperature data of a climatological station to the nearest Aladin grid point value: Because the climatological stations had not been taken into account by the Aladin model, it was expected to receive poor fitting results at these locations. It was found out that Aladin approximated well the daily minimum but very often underestimated the daily maximum temperature for the mountain stations (Figure 6).

Comparison of the point scale temperature data of a climatological station to the nearest Aladin grid point value, interpolated as a potential temperature: When the Aladin temperature field is re-interpolated into an 8 km grid (that is used by ISBA) the dependency of the potential temperature on the atmospheric pressure could be used to restore the temperature at the known elevation of the 8 km grid. This method gives higher bias and lower correlation coefficients (R^2) compared to the simple interpolation (Table 1).

Comparison of the measured to the predicted precipitations at 3 h and 24 h step: The squared correlation between the 3h sums of Aladin precipitations and the measured precipitations at the point scale were below 0.35. The best results were achieved when using 24 h sums (Figure 7). As an average estimation, Aladin precipitations were usually higher than the measured values. That depended on the altitude of the grid cell, but also on the surrounding elevation patterns.

Comparison of the total (accumulated for the period 16/09/2002 to 20/02/2003) precipitation field produced by Aladin NWP and the point scale observations' interpolation: This check showed the larger Aladin precipitation field variability compared to the observations. The model produced higher values over the Stara Planina Mountain that were not observed in reality (Figure 8).

	Station Elevation	SIMPLE INTERPOLATION					POTENTIAL TEMPERATURE INTERPOLATION				
		Station	RMS	STDE	BIAS	R2	Station	RMS	STDE	BIAS	R2
SYNOPTIC STATIONS	160	Plovdiv	0.30	3.12	0.10	0.84	Plovdiv	0.32	3.31	3.31	0.75
	2376	vr.Botev	0.36	3.45	2.37	0.71	vr.Botev	0.37	3.58	3.58	0.77
	173	Chirpan	0.28	2.65	-0.62	0.89	Chirpan	0.28	2.82	2.82	0.88
	138	Elhovo	0.28	2.61	-0.47	0.90	Elhovo	0.28	2.78	2.78	0.86
	1750	Rojen	0.28	2.44	-0.21	0.86	Rojen	0.30	2.56	2.56	0.78
	2925	vr.Musala	0.33	2.78	2.56	0.78	vr.Musala	0.35	2.91	2.91	0.78
	392	Kazanlak	0.32	2.44	-2.06	0.87	Kazanlak	0.30	2.71	2.71	0.82
		AVERAGE	**0.31**	**2.79**	**0.24**	**0.83**	**AVERAGE**	**0.31**	**2.95**	**2.95**	**0.81**
CLIMATOLOGICAL STATIONS	723	Devin	0.49	2.97	-0.87	0.80	Devin	0.42	3.23	3.23	0.76
	743	Velingrad	0.45	2.64	-0.42	0.85	Velingrad	0.44	2.97	2.97	0.82
	556	Panaguirisht	0.35	2.58	2.55	0.87	Panaguirish	0.37	2.70	2.70	0.79
	400	Karlovo	0.51	2.68	-0.85	0.84	Karlovo	0.44	3.30	3.30	0.74
	1150	Chepelare	0.46	3.10	-0.43	0.79	Chepelare	0.42	3.08	3.08	0.77
		AVERAGE	**0.45**	**2.79**	**0.00**	**0.83**	**AVERAGE**	**0.42**	**3.06**	**3.06**	**0.79**

Table 1. Statistical results of the comparison between the measured air temperatures at the location of the synoptic and climatological stations and interpolated Aladin air temperatures of the adjacent grid point. RMS is the root mean square; STDE is the standard error; BIAS is the average bias and R2 is the squared correlation coefficient.

The overall analysis showed that except the precipitation field estimation, which contains the higher error, all other fields could be used without special transformation. To correct the effect of the precipitation field on the water balance the measured precipitations could be used through sequential update of the soil moisture and other ISBA variables with that ones computed by using measured precipitations.

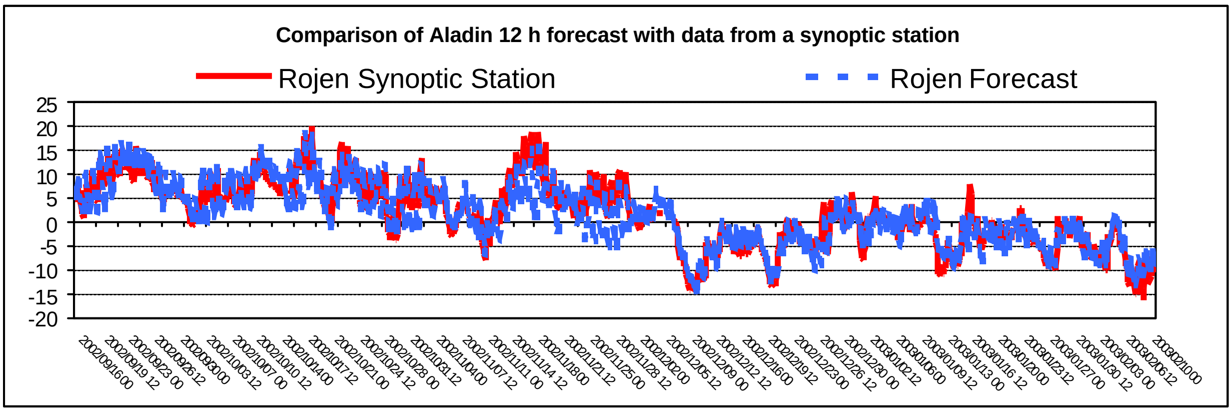


Figure 5 : Comparison between air temperature measured at a synoptic station and from the nearest Aladin grid point

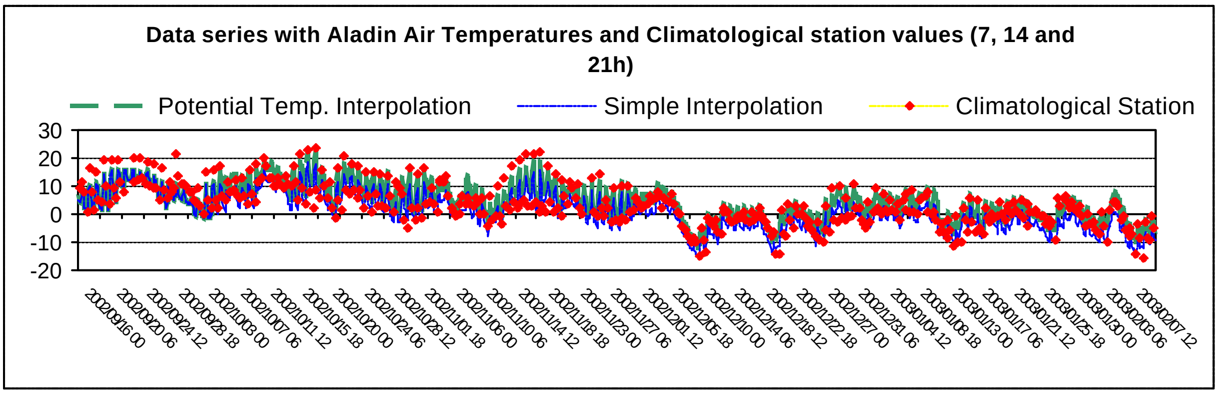
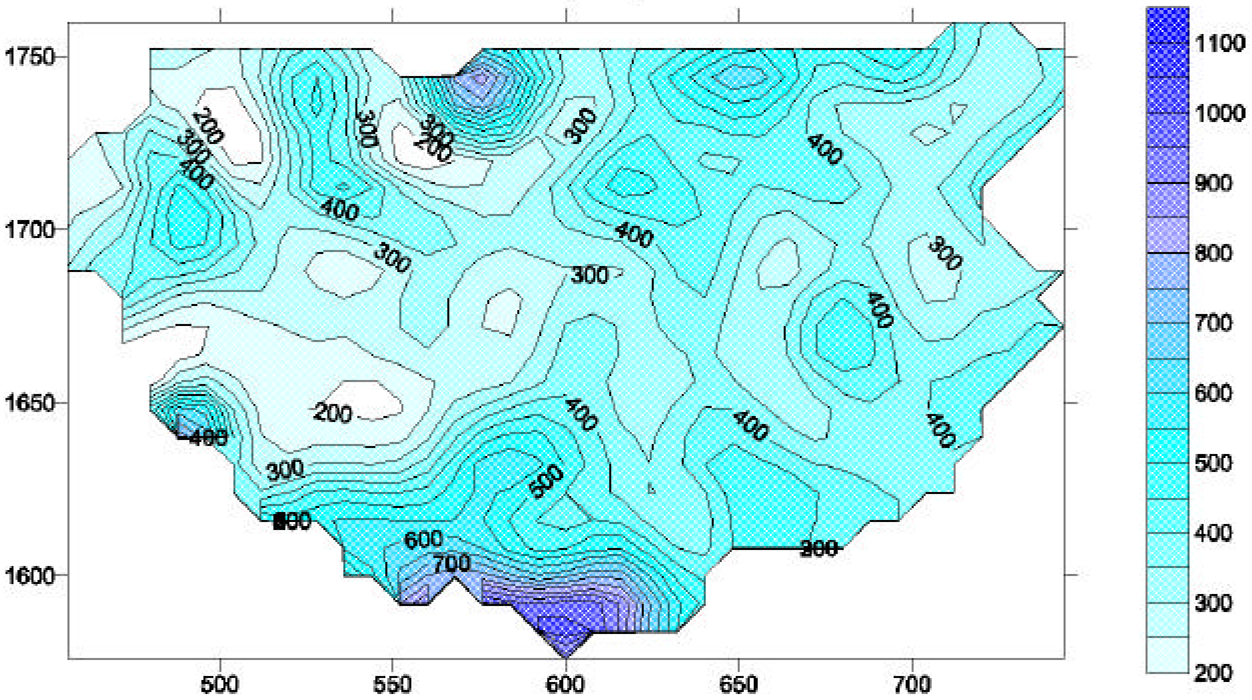
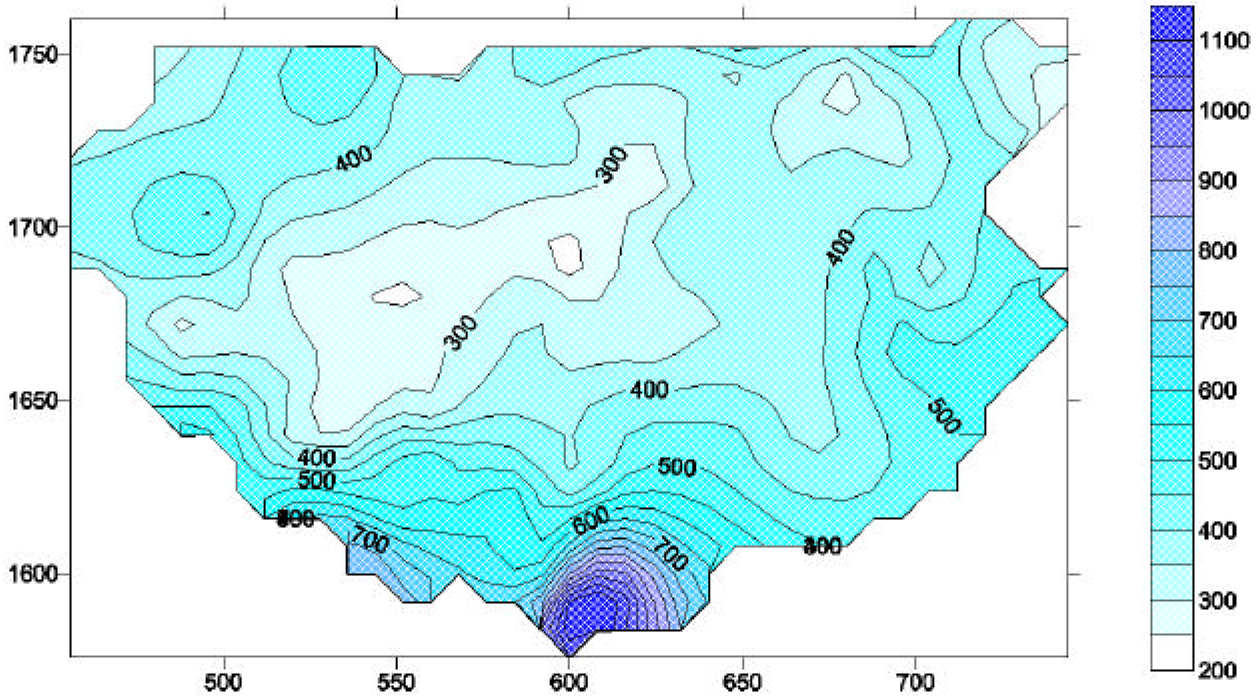


Figure 6 : Comparison between air temperature measured at a climatological station and from the nearest Aladin grid point



Aladin 12 h precipitation forecast



2D accumulated precipitations interpolated from the measured precipitations

Figure 8: Precipitations over the Maritza, Arda and Toundja River basins for the period 16-09-2002 to 20-02-2003 in mm

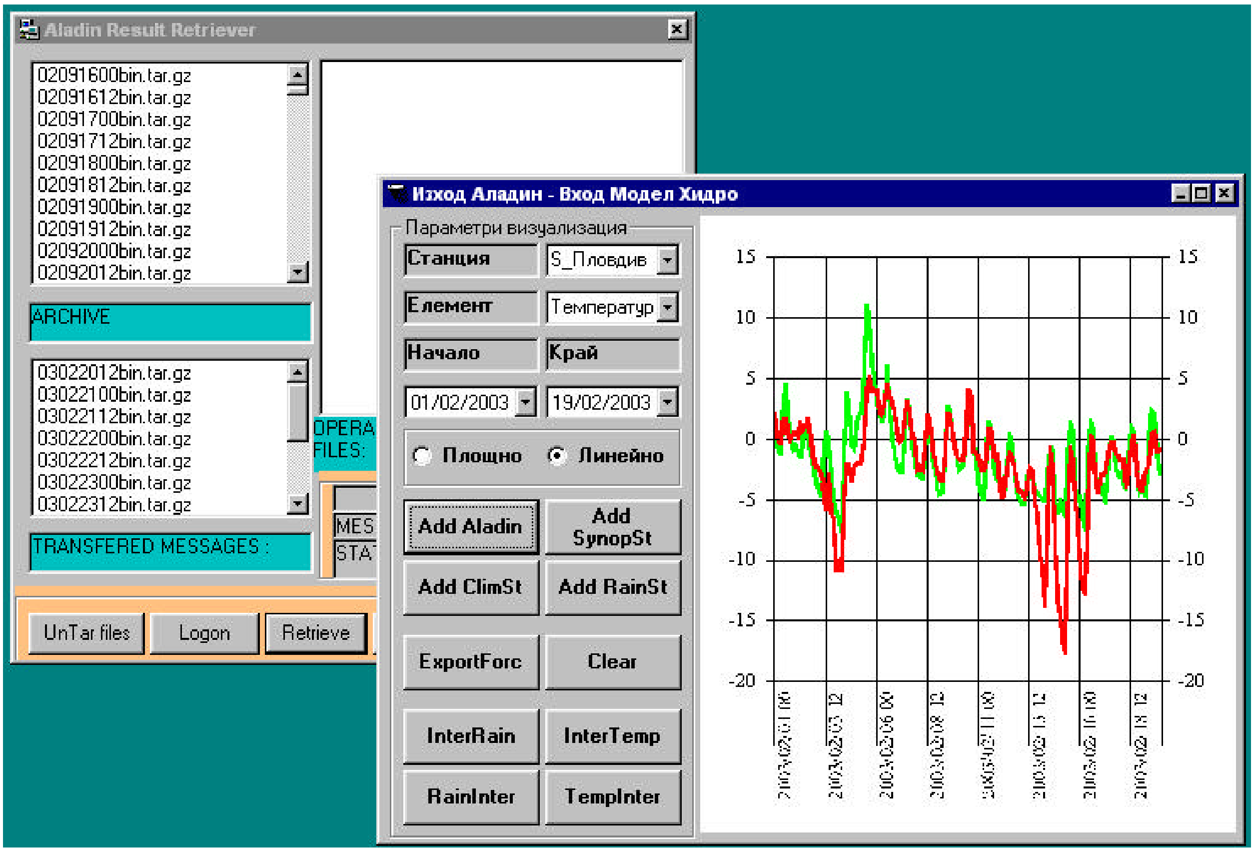
B. Automated field preparation

Despite the recently integration of ISBA, the Bulgarian version of Aladin model was developed without practical regard on the hydrologic modelling. Because of its horizontal resolution of 12 km, its outputs could not be used without interpolation by the ISBA-MODCOU model for the Maritza river basin that has a resolution of 8 km. So the first step, in order to use the Aladin fields for the hydrology was to interpolate the fields coming from Aladin into 8 km grid. For this purpose, a Win32 tool was developed in Visual Basic – IntraMod (Figure 9), which performed automatically the following tasks:

Download by FTP (file transfer protocol) the latest Aladin fields in binary format with a resolution of 12 km. This task was performed each 12 hours, corresponding to the model forecasts output.

The 8 fields: Air Temperature at 2m; Wind Speed; Relative Air Moisture; Atmospheric pressure; Solid and liquid precipitations; Global Solar Radiation and Cloudiness were interpolated to the 8 km grid of ISBA.

From these fields the Specific Air Moisture and the Atmospheric Long Wave Radiation fields were computed.



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Станция: S_Пловдив
Елемент: Температур
Начало: 01/02/2003
Край: 19/02/2003
○ Площно ● Линейно

Figure 9: Visual Basic tool used for automating retrieval and interpolation procedures

The eight atmospheric parameters were stored as binary files, ready to be used by ISBA land surface scheme. *It is important to emphasize that while updating the binary file with the new forecast, the last 12 sets of 2D fields (36 hours) were updated with the new data. By this way, at each forecast range were kept for further use only the analysis + 3* *sets (12 hours) from the previous forecast. In the case of precipitations and global radiation 4 sets were kept.*

It retrieved from the real-mode database and interpolated the real-time precipitation data. For that purpose, the Surfer7 simple block krigging was used through a dynamic library. The resulting field was stored in binary format for further usage from ISBA. This task was performed at a 24 h step corresponding to the data arrival in the real-mode database.

Additionally the IntraMod tool can perform in manual mode:

Graphical comparison between point scale observations from the real-mode database and the nearest interpolation grid point of the same variable.
Visualisation of the interpolated fields using Surfer7 dynamic library.
Export of the visualized graphics in graphic or text mode.

C. Adaptation of ISBA-MODCOU coupled system for using Aladin precipitation fields

As mentioned, the only use of Aladin precipitations was expected to produce largely overestimated runoff, caused by the overestimated precipitation. That is because the initial conditions (soil moisture, soil temperature, snow density and height) had to be corrected after one or two days of surface scheme integration. The values for the re-initialisation were taken from another ISBA integration having a delay of one or two daily steps (Noilhan, 2002), which used measured precipitations instead of Aladin outputs.

As a result the following four simulations were performed:

(C) Control simulation. 2D fields of measured precipitations were used for the control simulation. All the other input data were taken from Aladin 12 h forecast. The last 48 h were also included as 48 h forecast.
(S0) Simulation using full set of Aladin produced 12 h forecast. The last 48 h were included as 48 h forecast.
(S1) Simulation during which, ISBA prognostic variables were updated with the values taken from the control simulation at 24 h time step.
(S2) Simulation during which, ISBA prognostic variables were updated with the values taken from the control simulation at 48 h time step.

By this way three set of results could be compared to the control simulation Two time steps were tested for the re-initialisation of ISBA prognostic variables: 24 h and 48 h. The Table 2 shows the linear trend squared correlation coefficients (R^2) between the measured streamflow, the control and the corrected simulations for two anthropogenized and two natural river streamflows.

R^2	Catchment Surface [km^2]	Measured Streamflow	Control Simulation	S0 Simulation	S1 Simulation	S2 Simulation
Maritza Svilengrad (anthropogenized)	20840	1.0	0.64	0.27	0.43	0.39
Tundja Elhovo (anthropogenized)	5551	1.0	0.36	0	0.10	0.07
Chepelarska Bachkovo (natural)	825	1.0	0.65	0.09	0.44	0.44
Arda Vehtino (natural)	857	1.0	0.82	0.44	0.77	0.75

Table 2: Statistical results - squared correlation of the comparison between the four performed simulations and the measured daily streamflows.

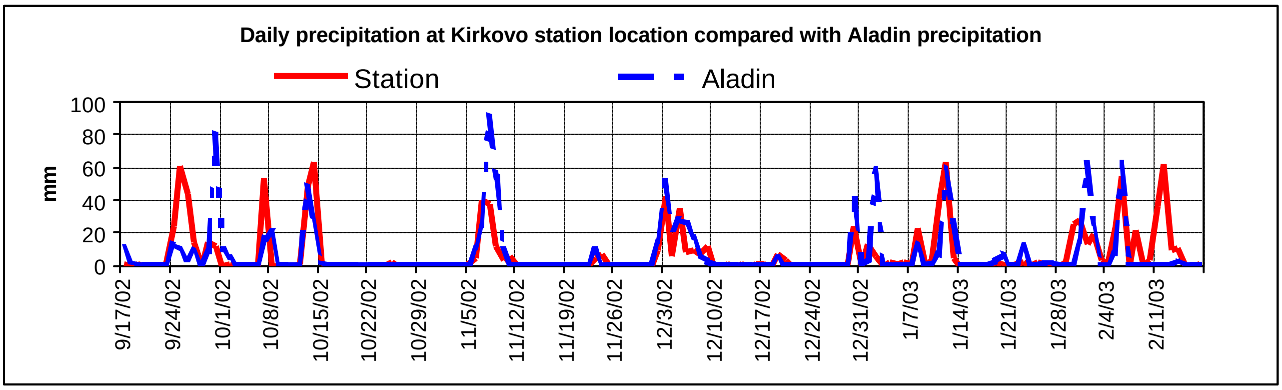

Figure 7 : Comparison between daily sum of precipitation at a rain gauge station and the predicted precipitation at the nearest Aladin grid point

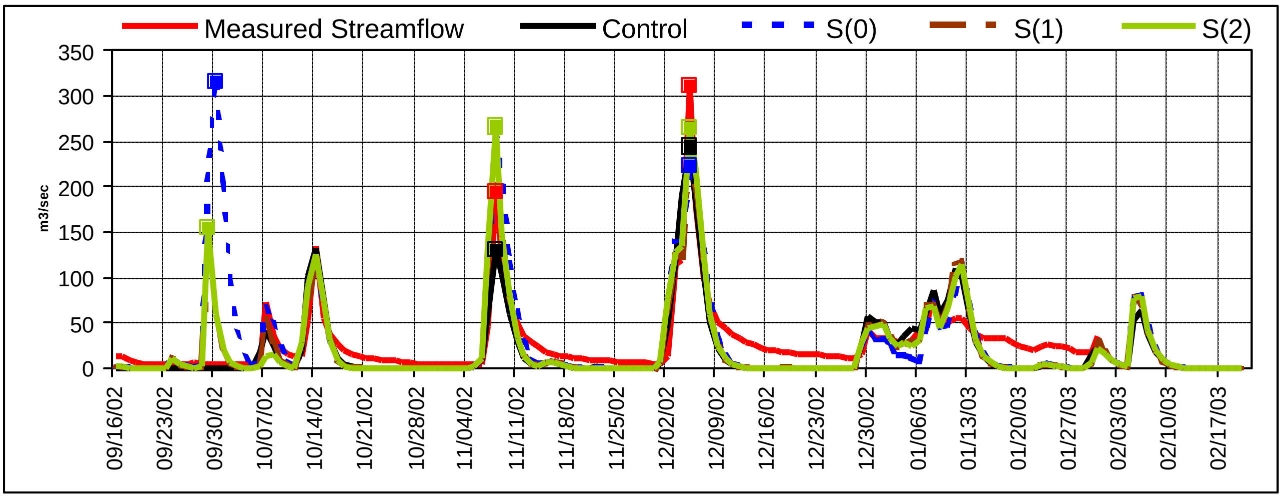

Figure 10 : Results of daily streamflow simulation and forecast for the Arda River catchment at Vehtino location in the South part of the region. One can see that the S1 and S2 simulations have diminished the effect of a false precipitation event (see Figure 7) occurred on the 30.09.02

Conclusion

As final result of the testing, one can point out that:

High resolution, short range outputs from Aladin model can be used for the purpose of hydrologic modeling.

For the forecast use, it is not possible to avoid inclusion of real and near-real time measured precipitations.

The on line ISBA land surface scheme variables (soil moisture, soil temperature, snow height and density etc.), computed with use of predicted Aladin precipitations, with values worked out with use of measured precipitations, have to be updated at the shortest possible intervals, which is driven by the availability of new real time 2D precipitation fields.

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