On the use of ISBA & SURFEX modelling platform applications in NIMH - Bulgaria

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Applications developed at basin level: objective flood forecast and water balance applications

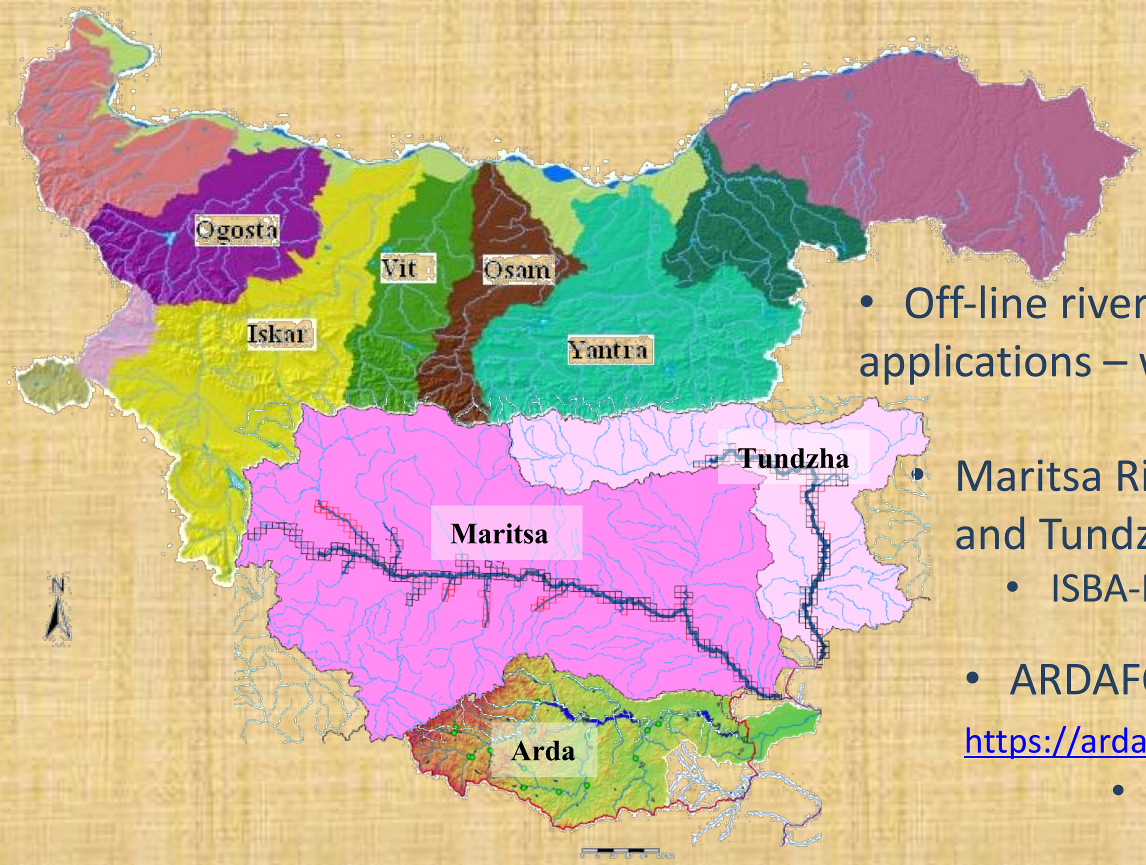
- Web published river flow simulation and forecasting applications
- SWE simulation for the management of big dam lakes storage capacity
- Validation of basin level annual water budget
- H-SAF H14 (H08) satellite products validation

Energy and water flux experiments at specific sites – objective: to assess SURFEX

- Energy and water budget compared to measures
- Energy budget compared to measures and climatology
- Soil moisture and snow pack evolution simulations

Next steps

2nd SURFEX User Workshop
Toulouse, 18 March – 20 March 2019



- Off-line river flow diagnosis and forecasting applications – with Web publishing
  - Maritsa River basin, including tributaries Arda and Tundzha Rivers
    - ISBA-Modcou (ISBA 2L) – Mike 11 (DHI)
  - ARDAFORECAST project for Arda River basin
    https://arda.hydro.bg/index.php?glaven=alertmap
    - SURFEX-TOP (7.3)
  - Upper Tundzha River basin
    - SURFEX (8.1) – 3-L + routing

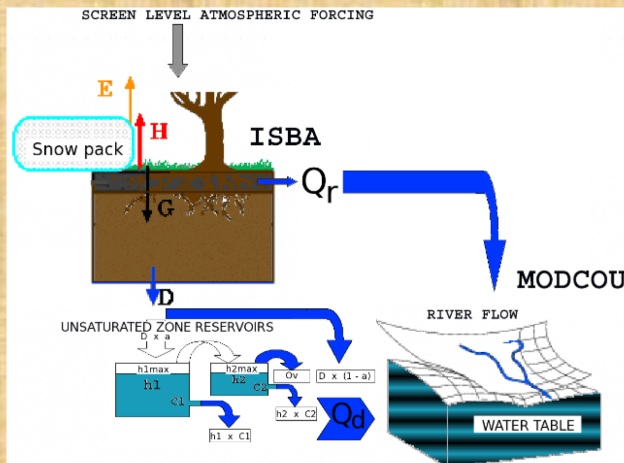
- Danube river tributary basins: Ogosta, Iskar, Vit, Osam, Yantra - SURFEX – routing TOP

The set-up was made within the PhD thesis of N. Nedkov and further developed within the project **"Danube WATER integrated management"**.

The project included the set-up of on-line system for river flow forecasting at 5 locations – near to the outlets of main Bulgarian Danube tributaries.

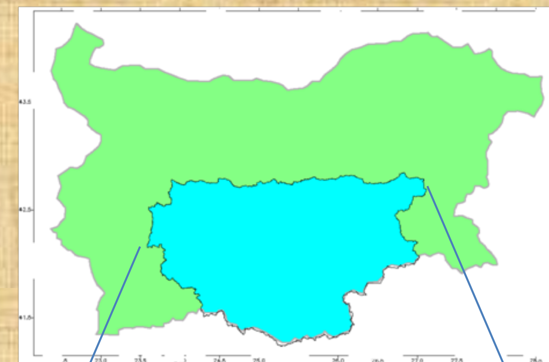
Coupled system ISBA-Modcou with unsaturated zone reservoirs

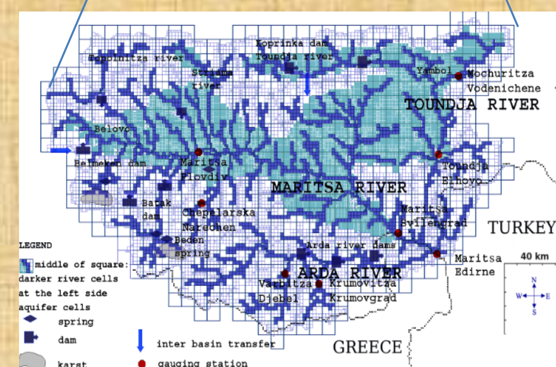
ISBA - Modcou coupled system was implemented in NIMH – Bulgaria for Maritsa river basin (about 34000 km^2) in 2006 on the basis of the development in Météo-France with the additional reservoirs for drainage water described in (Artinyan et al., 2008). The models are running in ***offline*** mode with input data time step of 3h over 638 grid cells (8*8 km).



Discharge is simulated and ***forecasted*** for ***80 river stations***. Data series include inflows for the big reservoirs in the area.

The system runs on a 12 hours schedule following ALADIN-BG output schedule.



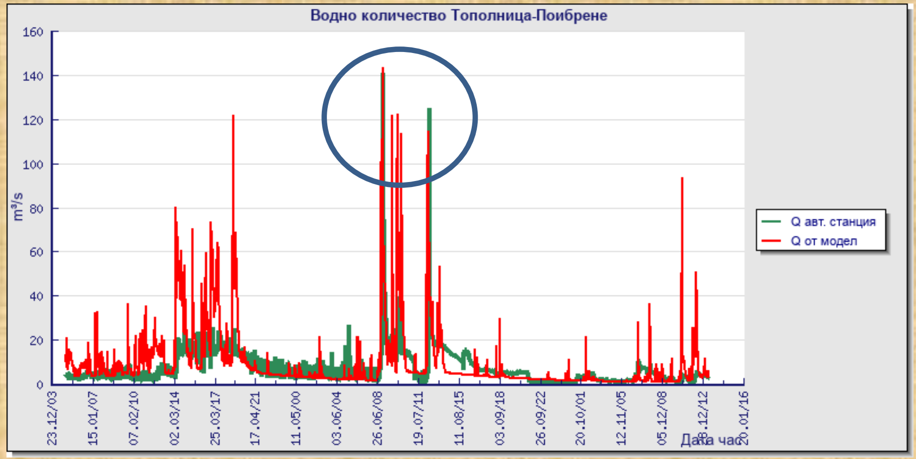


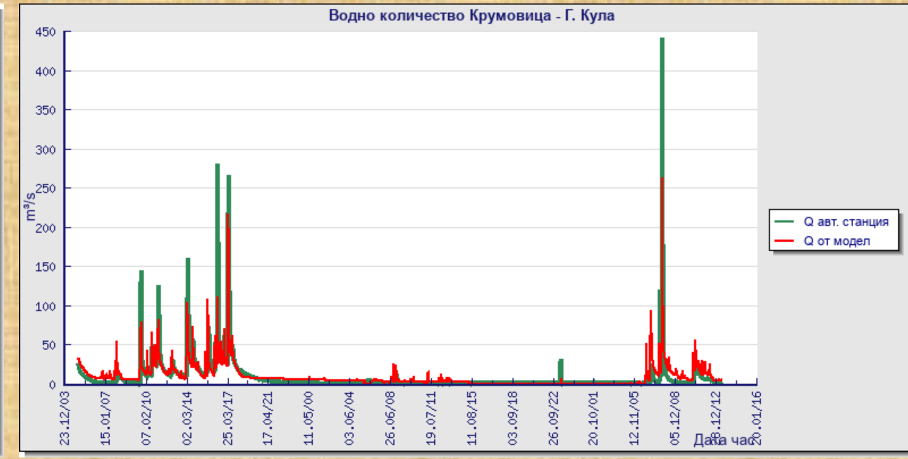
The system first runs the model (in restart mode) with “real-time” measured data input and then follows a “forecasting” run with 72h input data from ALADIN-BG. The second run uses the previous run results for initialization. That permits to have discharge data series as “real-time” simulation and forecasted ones. Input and output series and spatial fields are stored in a MySQL database and visualized in web browser.

RESTART conditions → Diagnostic run – 4 days → New Initial conditions → Forecasting run – 72 hours

Real-time fields

Forecasted fields



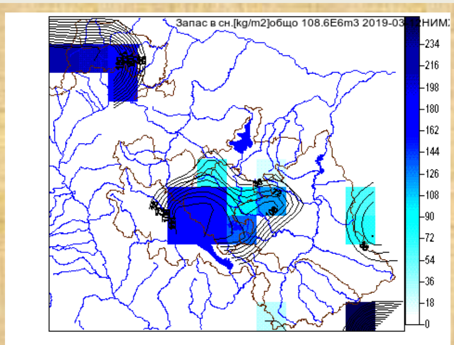


2018 year 3 h comparison for mountain catchment – model in **red**, automatic gauge in **green**

2018 year 3 h comparison for Mediterranean catchment – model in **red**, automatic gauge in **green**

	"measured vs real-time"	"real-time vs forecast"		
Catchment type	R^2/NS	24h-R^2/NS	48h-R^2/NS	72h-R^2/NS
Mediterranean	0.79/0.76	0.88/0.88	0.86/0.84	0.80/0.79
Mountain	0.48/0.33	0.73/0.58	0.71/0.59	0.66/0.57
Large-perturbed	0.48/-0.07	0.93/0.91	0.86/0.77	0.84/0.78

2015-2018 - 4 years statistics for typical catchments



Snow water equivalent at 12.03.2019 [kg/m^2] in Western Rhodopy mountain

- Off-line daily SWE simulation for the management of big dam lakes storage capacity for the Ministry of Environment and Water (MOEW)

ISBA (2L) – Modcou system "**strong sides**":

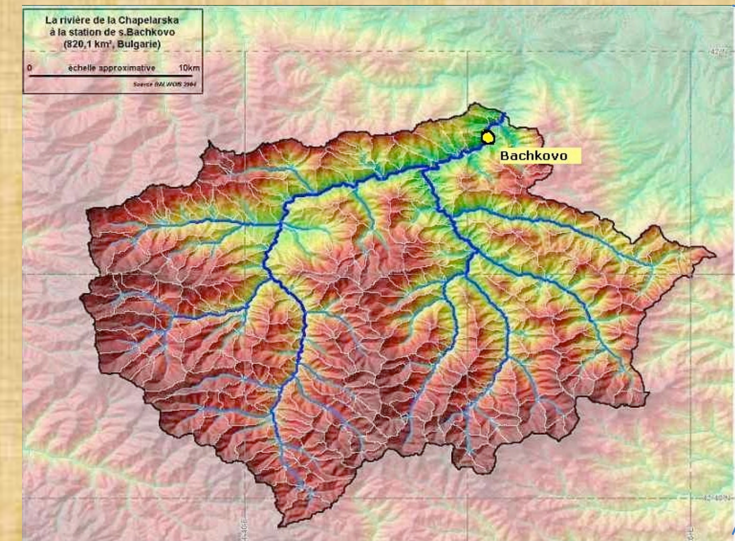
- Reliable input data on precipitations as result of preprocessing for Maritsa basin
- Good enough results without new calibration

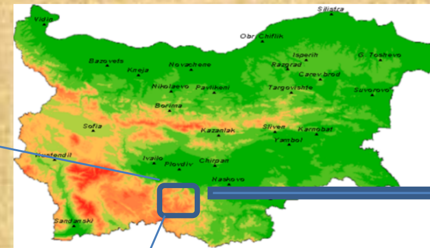
"weak sides" for the streamflow forecast:

- Lack of « assimilation » feature for the forecasting – particularly streamflow discharge
- Need of soil maps for other basins

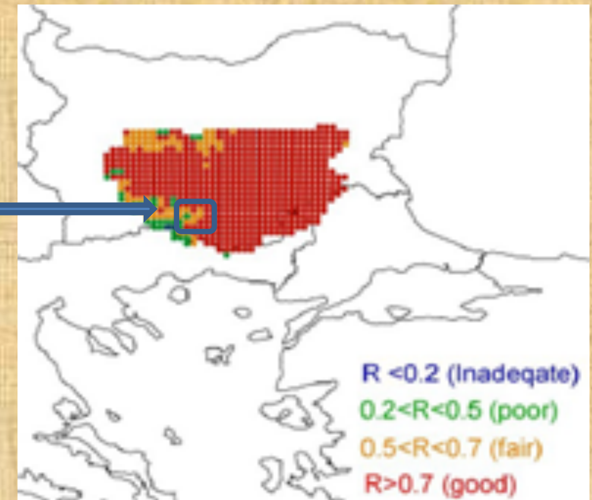
Hydrological model ISBA-Modcou - H-SAF H14 root zone SM product validation

Chepelarska river, Rodopi mountain

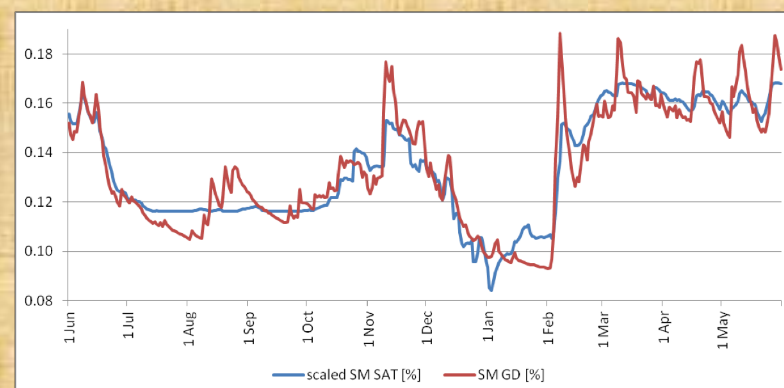




High altitude area prone to freezing in winter – has different soil moisture properties and behavior



Results of H14 over Maritsa basin (Albergel, November 2013, H-SAF meeting)



Comparison of spatially averaged re-scaled H14 (**blue**) to model root (D2) layer SM (in **red**) for May-2016 - June 2017.

H14 data can be used to enhance ISBA-Modcou simulation results by “replacement (insertion)” in model diagnostic D2 field, however H14 data has to be previously rescaled and fitted to model’s data at catchment level.

ISBA-Modcou and SURFEX - large basin level water budget experiments

Objective: to assess the methods of obtaining water balance components at country level

Table 1. River flow estimation by different models or computing methods

Basin district	ERA	SURFEX	"Registered"	ISBA alone*	ISBA-Modcou**
	Method of water balance components estimation [m^3/s]				
Annual averages of river flow for year 2013					
Danube district	225.0	383.6	138.4		
Black Sea district	99.6	174.9	51.9		
East Aegean district	246.6	404.6	206.5	237.5	308
West Aegean district	108.2	182.2	116.4		
Annual averages of river flow for year 2014					
Danube district	417.8	614.0	324.3		
Black Sea district	110.7	268.5	66.6		
East Aegean district	393.9	600.3	282.9	427.8	400
West Aegean district	179.2	183.7	113.5		
Annual averages of river flow for year 2015					
Danube district	384.3	512.8	284.1		
Black Sea district	128.4	346.7	85.5		
East Aegean district	406.3	532.8	428.4	310.8	428
West Aegean district	127.2	204.4	154.0		

** Available for the East Aegean basin district only. **This column is computed from the modeled streamflow discharge for the three main rivers and the corresponding stations: Maritsa at Svilengrad, Tundzha at Elhovo and Arda at Ivaylovgrad.*

Table 2. Precipitation annual sums computed by different methods

Basin district	ERA	NHRMA	Sp-EUSat	Registered	ISBA-preprocess*
	Method of water balance components estimation [mm]				
Annual sums for year 2013					
Danube district	603.3	748.0		657.2	
Black Sea district	514.8	652.1		534.4	
East Aegean district	652.1	801.9		647.5	655.0
West Aegean district	750.9	955.4		726.4	
Annual sums for year 2014					
Danube district	1078.3	1167.5	1378.778	1051.1	
Black Sea district	890.7	1104.3	1107.166	1010.9	
East Aegean district	1132.4	1304.8	1505.958	1081.0	1121.06
West Aegean district	1271.8	1201.0	1340.398	919.4	
Annual sums for year 2015					
Danube district	726.1	835.5	1005.522	724.6	
Black Sea district	568.9	772.0	814.330	631.7	
East Aegean district	834.9	1057.2	1183.315	805.7	824.8
West Aegean district	948.3	1069.2	1134.283	786.0	

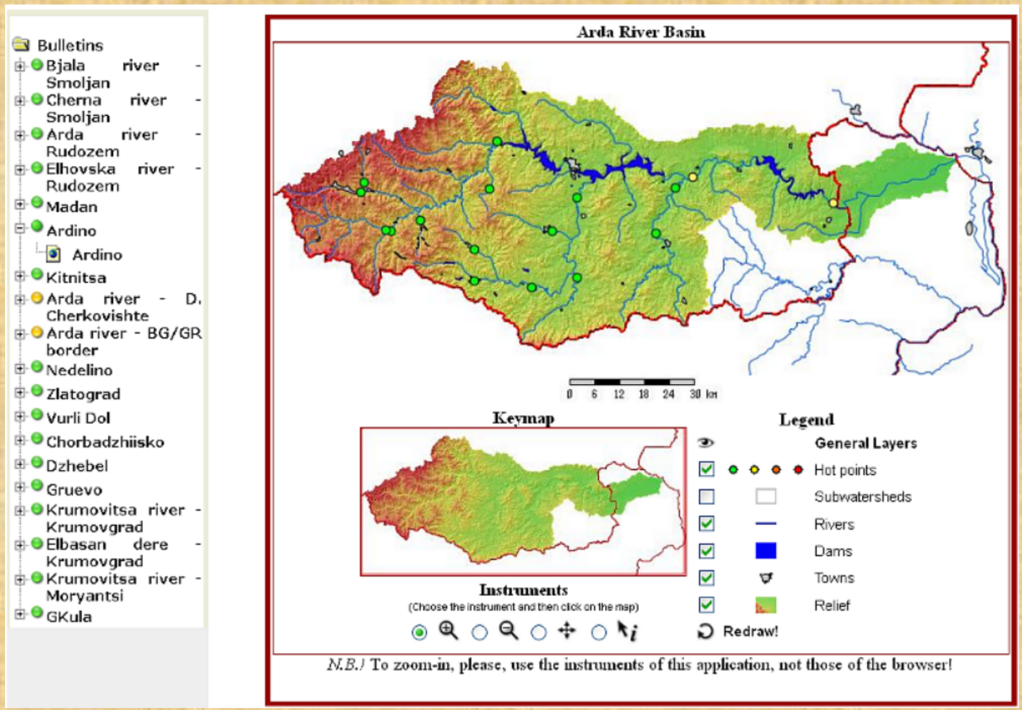
** Available for the East Aegean basin district only*

- Data in the table shows important differences of the RUNOFF between the 4 methods.
- Reason for differences - overestimated PRECIPITATION field in « Cressman analysis » (up-to 30%).
- ISBA-Modcou simulations show closer results to ERA Interim runoff over East Aegean River Basin as used precipitations are similar to ERA annual precipitation data and to "Registered" annual precipitation.

CONCLUSION: Real-time precipitation 3h fields available <u>at country level</u> are not satisfactory.

(Artinyan et al., 2017) https://www.danubeconference2017.org/images/e-book_full_texts_dc_2017.pdf

SURFEX-TOP (7.3) implementation in ARDAFORECAST project



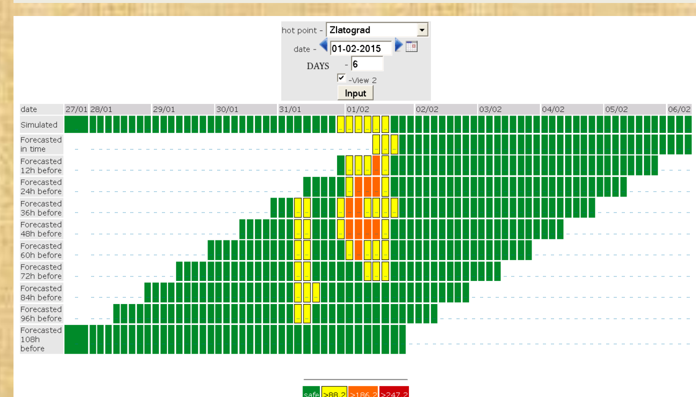
ARDAFORECAST was implemented for 2 years in 2012 – 2014. It was a joint effort of Bulgarian and Greek administrative and scientific partners. It aims to set-up and on-line system for flow forecasts at 18 locations in Bulgaria and at the border with Greece up-to *5 days ahead* with 3 h time step.

SURFEX – TOP parameters \CISBA=3-L\ were calibrated for the gauged river reaches and settings were applied to nearby un-gauged sections.

A separate routine for computing the forecasted water levels and dam overflows behavior of the tree big dam lakes

Web based mapping utility showing the hot-points alert levels in three colors: yellow (50% probability threshold), orange (20%) and **red** (1%) of the maximum water discharge at the location.

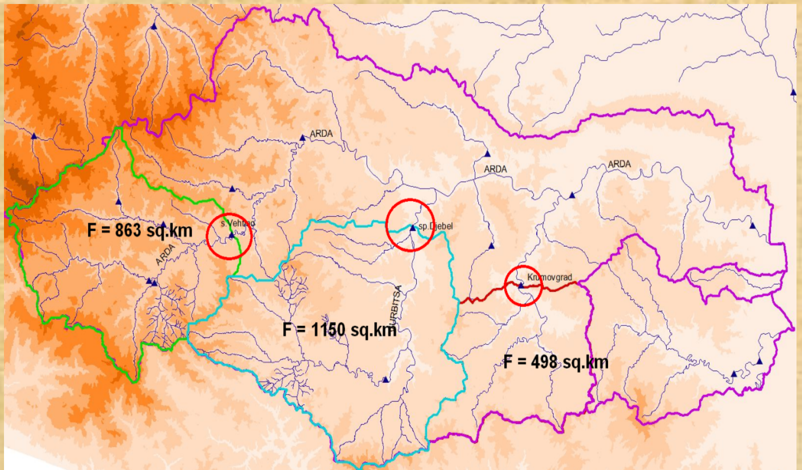
72 h forecast from ALADIN-BG (5 km)
2 additional days from ECMWF - HRES (9 km)



The analysis and forecasted series are presented as consecutive rows of boxes colored with the **alert level color**

https://arda.hydro.bg/index.php?glaven=techno
E. Artinyan et al. / Journal of Hydrology 541 (2016) 457–470

Follow-up after ARDAFORECAST project



SURFEX system **"strong sides"** in that kind of application:

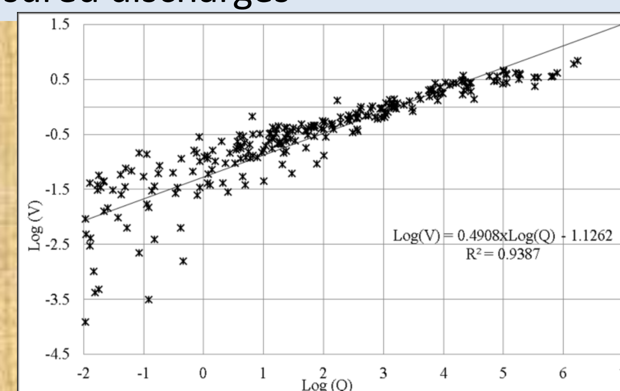
- Possibility to test and change the used schemes (CISBA=3-L, DIF) (CRUNOFF=TOPD, DT92, SGH) within the modeling system
- Use of standard land cover – ECOCLIMAP2

"weak sides" specially for forecasting purpose:

- river speed parameter – constant in time for the entire catchment (climatological and/or topographical parameter);
- for better forecasting results need to « start-up » with real-time measured discharges

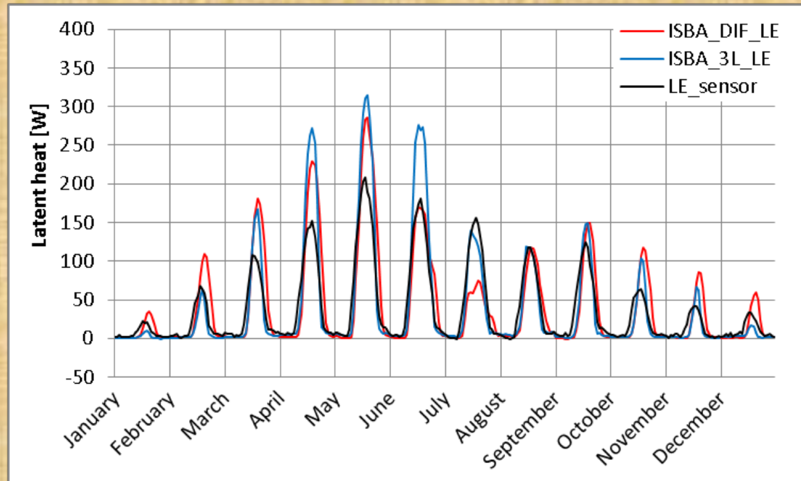
Experiments showed similar and better scores with other schemes beside CISBA=3-L & CRUNOFF=TOPD

SURFEX schemes and parameters					River	Statistical scores - validation period					
CISBA	CRUNOFF	CKSAT	NPATCH	G_LAYER		E	R^2	NRMSE%	FR^2	ComSt	Exec. Time
3-L	TOPD	EXP	1	3	Krumovitsa	0.621	0.815	3.0	**0.997**	0.850	100%
					Varbitsa	0.825	0.835	2.2	0.990		
					Arda	0.717	0.724	3.4	**0.955**		
3-L	DT92	SGH	3	3	Krumovitsa	0.803	0.808	2.2	0.995	0.856	11%
					Varbitsa	0.727	0.797	2.8	0.973		
					Arda	0.730	0.764	3.3	0.925		
DIF	DT92	DEF	3	11	Krumovitsa	0.810	0.867	2.1	0.996	0.890	17%
					Varbitsa	**0.875**	**0.891**	**1.9**	0.990		
					Arda	0.735	0.787	3.3	0.916		
DIF	DT92	DEF	19	11	Krumovitsa	0.819	0.863	2.1	0.994	0.888	43%
					Varbitsa	0.869	0.887	**1.9**	**0.991**		
					Arda	0.740	0.785	3.2	0.888		
DIF MEB AST	DT92	DEF	19	11	Krumovitsa	**0.828**	**0.873**	**2.0**	**0.997**	0.897	58%
					Varbitsa	0.872	0.888	**1.9**	**0.991**		
					Arda	**0.764**	**0.795**	**3.1**	0.948		



River speed and discharge are inter-connected at the cross-section. Implementation in SURFEX-TOP code not theoretically funded because of different river speed scale.

Local scale energy and water flux SURFEX experiments – VALLEY (168m)



1-09-2014
1-04-2017

Simulated and measured monthly diurnal cycle of latent heat **LE** at the **valley** station.

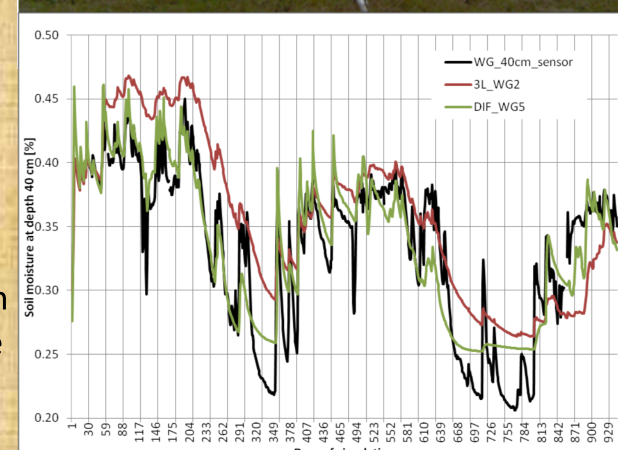
Overestimated LE for spring & summer months obtained with ECOCLIMAP2

Higher scores for G and WG are obtained with ISBA-DIF

Explicit input of soil water properties WFC, WWILT and WSAT will enhance results

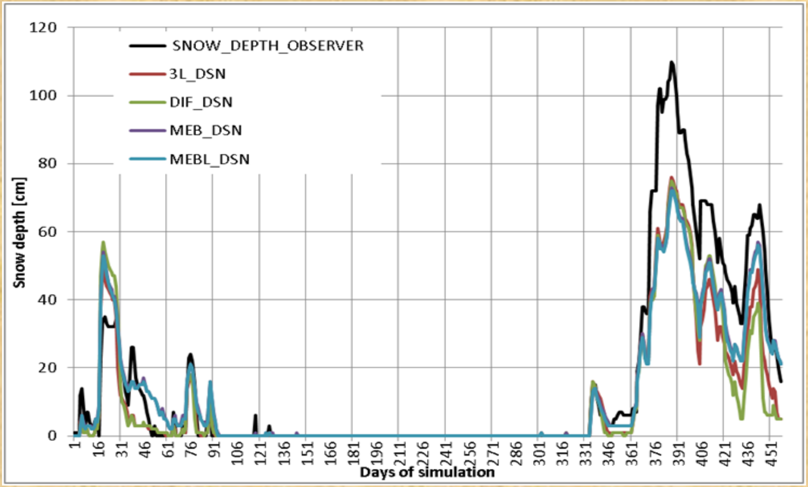
	SURFEX 8.1*		**SURFEX 8***	
	ISBA_3L		**ISBA_DIF**	
	R^2	**RMSE**	**R^2**	**RMSE**
H [W]	0.63	38.1	0.61	53.3
LE [W]	0.74	41.0	0.61	46.9
G [W]	0.59	36.6	0.69	27.3
Soil Temp. ST2/5	0.92	3.6	0.90	3.5
Soil Mois. WG2/5	0.74	0.11	0.81	0.09
Snow height OBS	0.77	6.5	0.74	11.6

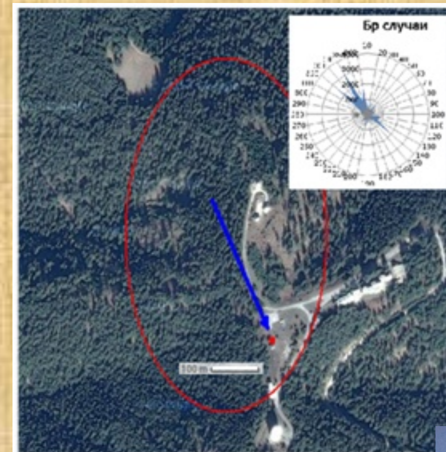
Statistical scores for the options **ISBA 3-L** and **DIF** for the valley site



Soil moisture simulation **ISBA 3-L** and **DIF** for the valley site compared to sensor measures

Local scale energy and water flux SURFEX experiments – FOREST 1750 м





Higher scores of ISBA-DF with MEB(L) energy scheme for many diagnostic variables except SWE

Snow height simulation ISBA 3-L, DIF, MEB and MEBL for the mountain site compared to OBS measures.

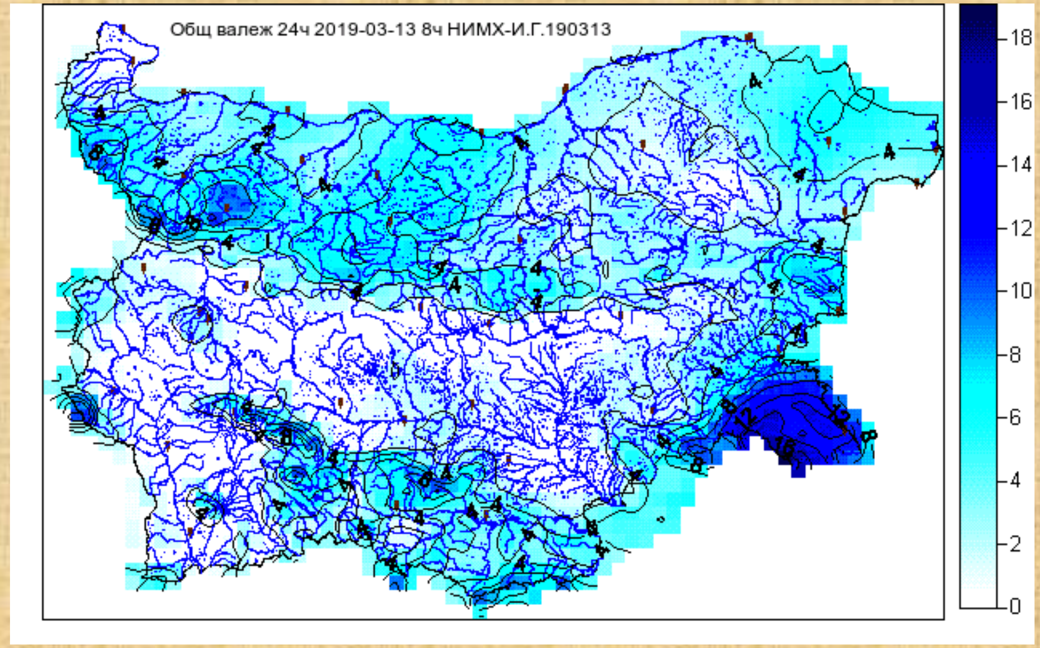
31-12-2015
1-04-2017

	ISBA_3L		ISBA_DIF		MEB		MEBL	
	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE
H [W]	0.67	71.3	0.69	60.7	0.68	59.0	0.74	62.9
LE [W]	0.58	45.8	0.63	44.5	0.56	50.7	0.62	40.6
G [W]	0.26	42.5	0.29	36.3	0.28	44.1	0.27	35.0
Soil Temp. ST2/5	0.79	3.49	0.76	4.31	0.77	4.43	0.77	4.17
Soil Mois. WG2/5	0.683	0.084	0.60	0.072	0.69	0.066	0.74	0.070
Snow SWE sensor	0.87	19.8	0.78	24.7	0.84	31.6	0.84	31.2
Snow height sensor	0.81	21.2	0.74	22.5	0.91	17.3	0.91	17.8
Snow water OBS $[kg/m^2]$	0.83	65.5	0.66	64.3	0.79	73.9	0.79	74.6
Snow height OBS[cm]	0.93	17.8	0.87	19.1	0.93	15.2	0.93	15.8

Statistical scores for the experiments with options
ISBA 3-L, **DIF**, **MEB** and **MEBL** for the mountain site with pine forest

Some thoughts on required next steps….

IMORTANT
- An effort is needed to enhance real-time 3h fields at country level
- Preparing and using WFC, WWILT and KSAT fields at country level
- Development of RAPID (Cedric David) application at country level for streamflow simulation and forecast.



SECONDARY
- Reduction of input spatial and temporary step to 4 km and 1 h.
- Further analysis on water balance at basin and country level with high quality meteorological forcing
- Investigation of possibilities for underground water storage simulations

Thank you !