Bulgarian Journal of Meteorology and Hydrology

Национален институт по метеорология и хидрология

National Institute of Meteorology and Hydrology

Bul. J. Meteo & Hydro 24/2 (2020) 1-14

Verification of the regional numerical weather prediction with ALADIN-BG in Bulgaria

Boryana Tsenova*, Rilka Valcheva

National Institute of Meteorology and Hydrology,
Tsarigradsko shose 66, 1784 Sofia, Bulgaria

Abstract: In this paper verification results of different meteorological elements forecasted by ALADIN-BG model over the territory of Bulgaria are presented. ALADIN-BG is operational at the National Institute of Meteorology and Hydrology since 1999. Since, it has undergone great development. On average every two years it switches to a new version that includes updates based on scientific developments. Since November 2019, the operational version is based on cy43t2. Verification statistics of the operational forecasts for temperature and relative humidity at 2 m, wind velocity at 10 m and 12 hours accumulated precipitation are computed by interpolating ALADIN-BG output to observation points of 40 synoptic stations in Bulgaria. Results for the period between January and August 2020 are presented.

Keywords: verification, numerical weather prediction, ALADIN

1. INTRODUCTION

Numerical weather prediction (NWP) models driven by global model output provide valuable short-term weather forecasts at regional scales with refined model grids and customized model physics. Over the last decade, NWP forecasts have become more sophisticated largely due to significant advances in computational resources, resolution and improved parameterisation schemes. However, model skill varies depending on the meteorological parameter and the forecast lead time being evaluated. Model forecasting is affected by initial and boundary conditions, numerical approximations of the dynamical equations, and simplifications of the complex atmospheric physical and chemical processes. As a result, NWP model forecasts are subject to systematic (biases) and random errors (Ebert and McBride, 2000; Sun et al., 2003). Forecasts of

* boryana.tsenova@meteo.bg

surface- and boundary-layer variables rely heavily on surface conditions, that include soil temperature and moisture, land surface, and the coupling between such parameters within the land-surface model. Investigating the characteristics of model-forecast errors is imperative for providing useful guidance to end-users and model developers as well.

ALADIN model is a spectral model for regional forecast of meteorological fields and elements. Its development is being done by a consortium of 16 member countries with Météo-France as a leading partner (https://www.umr-cnrm.fr/aladin/). ALADIN-BG is used as operational NWP model at the National Institute of Meteorology and Hydrology in Bulgaria more than 20 years and for all these years it has undergone great development. On average every two years the operational model switches to a new version that includes updates based on scientific developments. Local model verification tools are developed in NIMH during the last years (Tsenova and Bogatchev, 2019).

In the present paper results of the verification of some meteorological elements forecasted by ALADIN-BG (based on cy43t2, which is operational since November 2019) versus synoptic measurements in Bulgaria during the period January - August 2020 are presented. The paper is organized as follows: Section 2 describes in more details the model ALADIN, Section 3 – the methodology used in the study, while Sections 4 and 5 respectively results and conclusions.

2. ALADIN-BG

The ALADIN (Aire Limitée Adaptation Dynamique Développement International, International development for limited-area dynamical adaptation) System is the set of pre-processing, data assimilation, forecast model and post-processing – verification software codes shared and developed by the partners of the ALADIN consortium to be used for running a high-resolution limited-area model (LAM) for producing the best possible operational numerical weather prediction (NWP) applications based on a configuration compatible with their available computing resource (Termonia et al., 2018). Bulgaria through the National Institute of Meteorology and Hydrology (NIMH) is in the ALADIN consortium since 1992, and ALADIN is operational in the institute since 1999. ALADIN uses a spectral dynamical core with a two-time level semi-implicit semi-Lagrangian scheme. ALADIN-BG is coupled with SURFEX, the surface modeling platform developed by Météo-France in cooperation with the scientific community. Nowadays, the operational model configuration at NIMH is the following: the integration domain is covering a big part of the Balkan Peninsula, centered on Bulgaria, with a horizontal resolution of 5 km, 105 vertical levels, a time step of 300 s and a forecast range of 72 h. It is run twice daily, at 06 and 18 UTC and it uses the global ARPEGE of Météo-France (Courtier and Geleyn, 1988; Courtier et al., 1991) output for initial and boundary conditions. Since November 2019, the operational model in NIMH is based on cy43t2.

3. METODOLOGY

Verification statistics of the operational forecasts for the period January-August 2020 for temperature and relative humidity at 2 m, wind velocity at 10 m and 12 hours accumulated precipitation are computed by interpolating ALADIN-BG output to observation points of 40 synoptic stations in Bulgaria. Figure 1 shows the synoptic stations locations on the post-processed by ALADIN-BG altitude, as well the model grid points. For some of the stations, model data for temperature were interpolated to stations coordinates horizontally using bi-linear interpolation and then vertically using a mean lapse rate of 8.5 K/km. For these stations, model data for relative humidity, wind speed and 12h precipitation were also interpolated using bi-linear interpolation. For other stations preliminary analyses showed that verification results were better when using the closest model point. At every forecast hour (separately in each run), BIAS and RMSE are calculated as follows:

$$BIAS = \frac{1}{n}\sum_{i=1}^{n}\left(Xforecast_i - Xmeasured_i\right)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(Xforecast_i - Xmeasured_i\right)^2}{n}}$$

where *Xforecast* is the forecasted by ALADIN-BG meteoelement, while *Xmeasured* – the measured in the corresponding station. In the present study, first mean monthly BIAS and RMSE of the considered meteoelements as a function of the forecast range for each month (from January to August) for the two daily model runs (at 06 and 18 UTC) are presented. Then mean BIAS and RMSE of the meteoelements for the whole period for each synoptic station are shown.

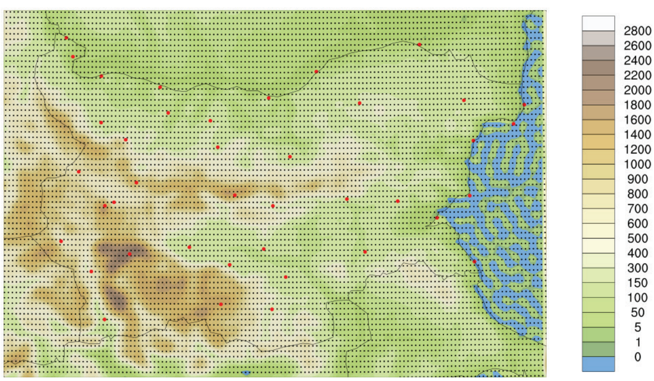

Fig.1. Location of the synoptic stations (red points) in Bulgaria on the post-processed model altitude (the black points show the model grid)

4. RESULTS

Figures 2-5 show mean monthly BIAS and RMSE of temperature at 2 m, 12 hours accumulated precipitation, relative humidity at 2m and wind velocity at 10 m as a function of the forecast range for each month (from January to August) in 2020 for the two daily model runs (at 06 and 18 UTC). The monthly mean BIAS for the temperature at 2 m (Figure 2) is between –1.5 ^{o}C and 1 ^{o}C, while the RMSE is between 2 ^{o}C and 3.5 ^{o}C. There is a visible diurnal trend of the two forecast runs – during the night hours ALADIN-BG underestimates 2m temperature especially in winter months. In January the mean RMSE was the highest in comparison to other months, especially during night hours. Results from last year (not shown here) showed that in 2019 the highest mean monthly RMSE was in February, also a cold winter month. For the accumulated in 12 hours precipitation (Figure 3) it is visible that the monthly mean BIAS is positive and below 1 mm for all months and the mean RMSE is between 1 mm and 3.5 mm. It could be generalized that ALADIN-BG tends to slightly overestimate the 12h precipitation. During the summer months a diurnal trend is visible with an overestimation of the diurnal precipitation. In case of 2m relative humidity (Figure 4) the mean monthly RMSE is between 6-8% for all months while the mean BIAS is negative 3% for summer months (July, August) and ± 2% for the other months. A slight diurnal trend is visible for the mean monthly RMSE during the summer months, when ALADIN-BG slightly overestimates the relative humidity during the daily hours. For the monthly mean BIAS and RMSE for 10m wind (Figure 5) a negative BIAS of 1m/s for all months and RMSE between 2-3.5 m/s are visible. The biggest errors are shown during winter months.

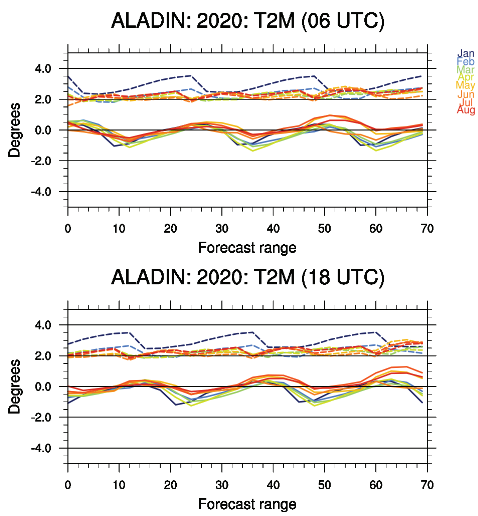

Fig. 2. Monthly mean BIAS (solid lines) and RMSE (dotted lines) as a function of the forecast range for all stations for the temperature at 2m (in ^{o}C) for the two model runs (at 06 UTC and 18 UTC).

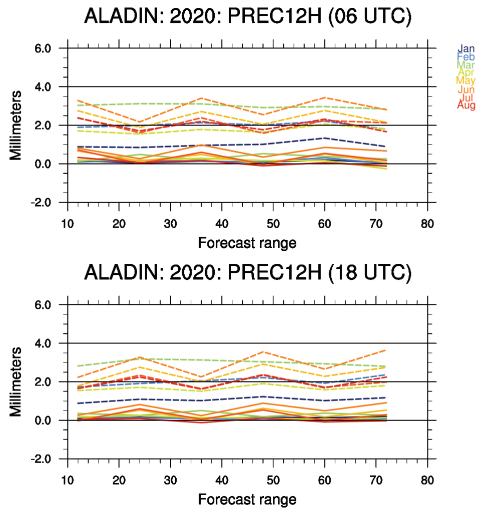

Fig. 3. Monthly mean BIAS (solid lines) and RMSE (dotted lines) as a function of the forecast range for all stations for the accumulated in 12 h precipitation (in mm) for the two model runs (at 06 UTC and 18 UTC).

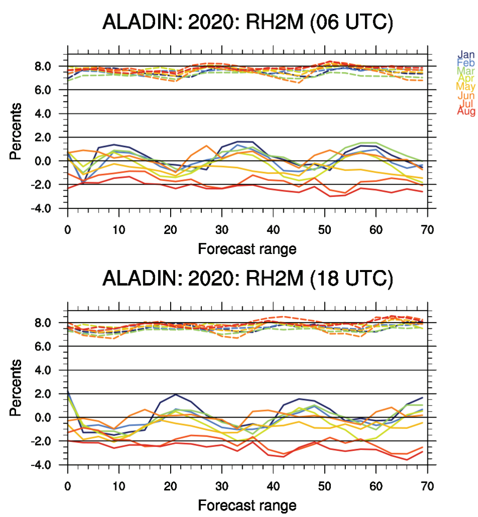

Fig. 4. Monthly mean BIAS (solid lines) and RMSE (dotted lines) as a function of the forecast range for all stations for the relative humidity at 2m (in %) for the two model runs (at 06 UTC and 18 UTC).

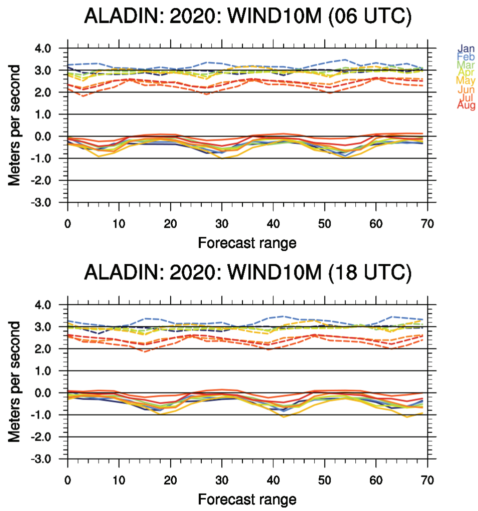

Fig. 5. Monthly mean BIAS (solid lines) and RMSE (dotted lines) as a function of the forecast range for all stations for the wind velocity at 10m (in m/s) for the two model runs (at 06 UTC and 18 UTC).

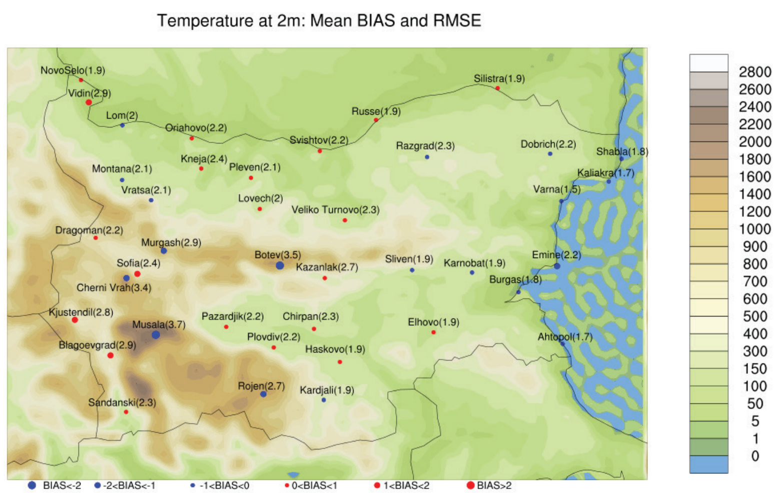

Fig. 6. Mean BIAS and RMSE of the temperature at 2 m (in ^{o}C) forecasted by ALADIN during 2020 (from January to August) for each station (coloured circles show the BIAS, while RMSE is indicated next to each station name)

In Figure 6 the mean BIAS and RMSE of the temperature at 2m for the whole considered period for each station are shown. From the figure it is visible that except for Vidin station, in all other stations located in the northern part of Bulgaria the mean

2m temperature BIAS is between -1 and 1 °C and the mean RMSE between 1.5 and 2.4 °C. Similar is the forecast accuracy in the lowland part of the southern Bulgaria, while in the mountainous western part of the country, stations mean BIAS and RMSE reach higher values. The highest 2m temperature mean BIAS (in absolute values) and RMSE are obtained in stations located at mountains peaks – Musala – 2925 m (mean BIAS=−2.6 °K and RMSE=3.7 °C), Botev – 2376 m (mean BIAS=−2.3 °C and RMSE=3.5 °C), Cherni Vrah – 2290 m (mean BIAS=−1.9 °C and mean RMSE=3.4 °C) and Murgash – 1687 m (mean BIAS=−1.9 °C and RMSE=2.9 °C).

In Figure 7, monthly mean BIAS and RMSE (based on model runs at 06 UTC) as a function of the forecast range for some of the synoptic stations with worse forecast results for 2m temperature in 2020 are presented. One can see that for Musala station (for other mountain peak stations is similar) daily temperatures are slightly underestimated by ALADIN-BG, while night temperatures – significantly, mean RMSE reaching values of 7°C in January. Further in-deep investigations are needed to explain such strong night temperature underestimations, that could be due to model physics, surface, forecast interpolation or any other reason. The other stations with higher mean absolute values of 2m temperature BIAS and RMSE in Figure 6 are those located close to mountains: Sofia – 595 m (mean BIAS=1.1 °C and RMSE=2.4 °C) – in the vicinity of Vitosha mountain, Blagoevgrad – 410 m (mean BIAS=1.6 °C and RMSE=2.9 °C) – between Rila and Pirin mountains, Kjustendil – 560 m (mean BIAS=1.2 °C and RMSE=2.8 °C) – close to Osogovo and Vlahina massifs. From Figure 7 it is visible that the relatively high mean RMSE is due to the RMSE is January and February, when ALADIN-BG overestimated the 2m temperature over Sofia; for other months, ALADIN-BG overestimates slightly daily temperatures. The Rojen peak station (1750 m) is also with a relatively high value of the 2m temperature mean BIAS (–1.6 °C) and RMSE (2.7 °C), while the coastal station at cap Emine (15 m) is with values of mean BIAS=−1 °C and RMSE=2.2 °C, mostly due to diurnal underestimation of the temperature during the summer months (Figure 7).

For Vidin station, which is on the boarder of Danube river a significant overestimation of night temperatures during all considered months in 2020 is visible (Figure 7), which is not the case for other synoptic stations at Danube coast (Novo Selo, Oriahovo, Svishtov, Ruse and Silistra). In Appendix are given all mean monthly BIAS (Table 1) and mean monthly RMSE (Table 2) for the 2 m temperature for each month for each synoptic station, based on the two model runs, at 6 and at 18 UTC.

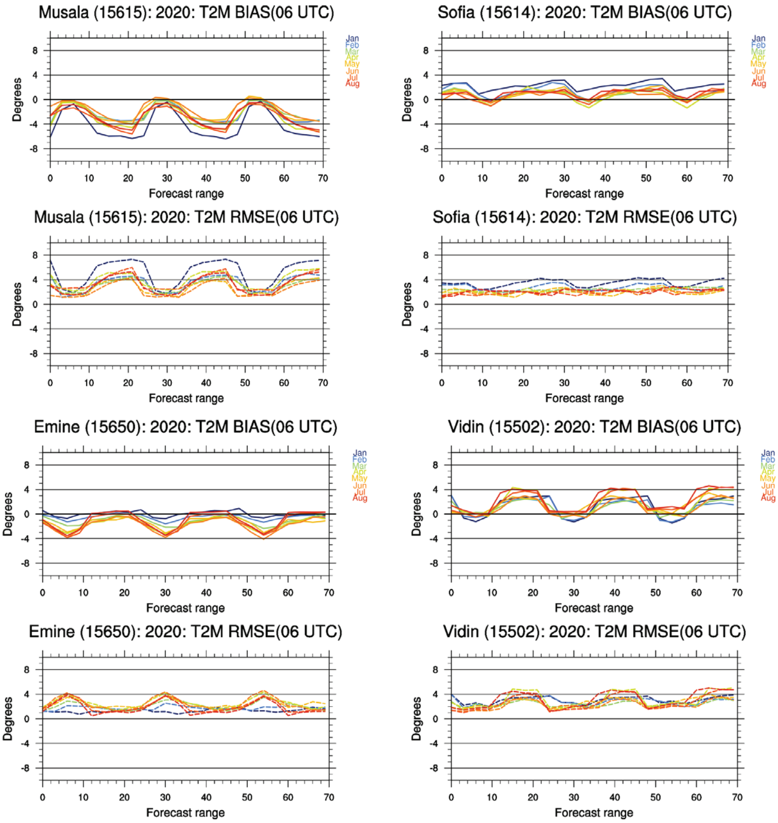

Fig. 7. Monthly mean BIAS and RMSE of 2m temperature (based on model runs at 06 UTC) as a function of the forecast range for some of the synoptic stations with worse forecast results in 2020: Musala, Sofia, Emine and Vidin

In Figure 8 the mean BIAS and RMSE of the 12h accumulated precipitation for the whole considered period for each station are shown. From the figure it is visible that for all stations the mean BIAS in absolute values is below 1 mm, except of peak Botev station with mean BIAS=1 mm, and only in sea coastal stations Shabla and Kaliakra ALADIN-BG tends to underestimate the 12h precipitation. The mean RMSE is below 2.5 mm for all stations, with exceptions for mountain peaks Musala, Cherni Vrah, Murgash and Botev.

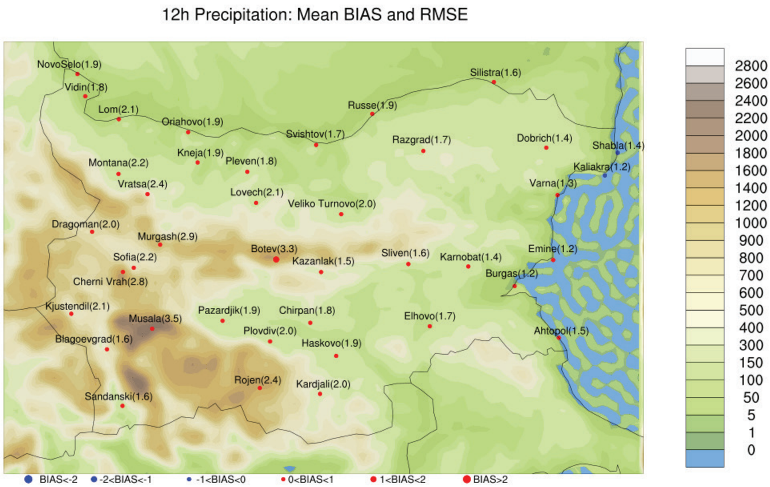

Fig. 8. Mean BIAS and RMSE of 12 h accumulated precipitation (in mm) forecasted by ALADIN during 2020 (from January to August) for each station (coloured circles show the BIAS, while RMSE is indicated next to each station name)

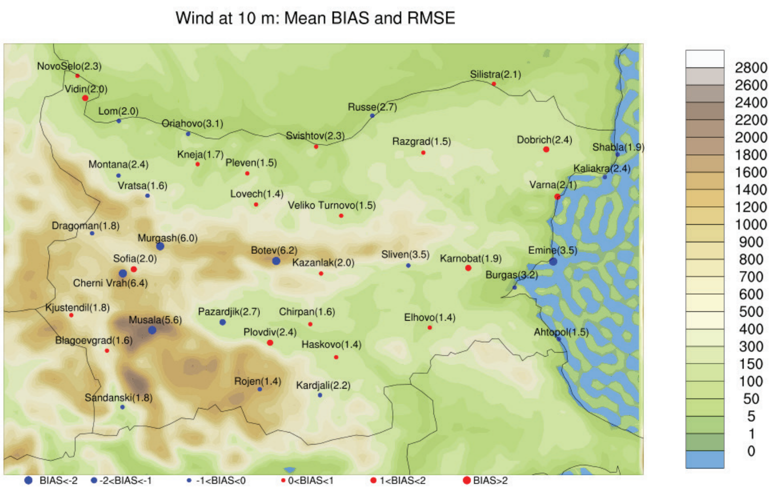

Fig. 9. Mean BIAS and RMSE of wind velocity at 10 m (in m/s) forecasted by ALADIN during 2020 (from January to August) for each station (coloured circles show the BIAS, while RMSE is indicated next to each station name)

In Figure 9 the mean BIAS and RMSE of the wind velocity at 10 m for the whole considered period for each station are shown. From the figure it is visible that for the majority of stations the mean BIAS in absolute values is below 1 m/s. At mountain peak stations, the mean wind speed BIAS are below –2 m/s and mean RMSE – around 6 m/s, which once again show high discrepancies between the forecast and the measurements (the forecast underestimating significantly the measurements). Also negative mean BIAS is visible in Black sea coastal stations, except of Varna station where it is positive. In case of 2m relative humidity (Figure 10) negative mean BIAS above 2% is in stations in central and western Bulgaria. The mean RMSE is between 7 and 8 % for all stations.

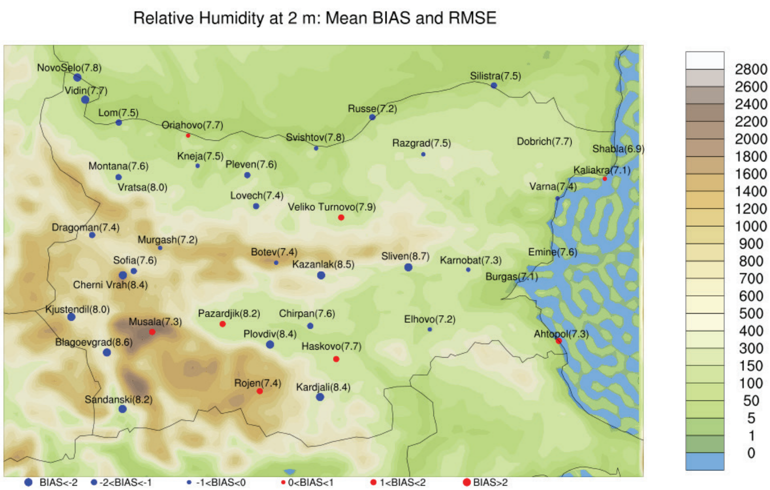

Fig. 10. Mean BIAS and root mean square error RMSE of the relative humidity at 2m (in %) forecasted by ALADIN during 2020 (from January to August) for each station (coloured circles show the BIAS, while RMSE is indicated next to each station)

5. CONCLUSION

In the present study, verification results of different meteorological elements forecasted by ALADIN-BG model over the territory of Bulgaria are presented. Verification statistics of the operational forecasts for temperature and relative humidity at 2 m, wind velocity at 10 m and 12 hours accumulated precipitation are computed by interpolating ALADIN-BG output to observation points of 40 synoptic stations in Bulgaria for the period between January to August 2020. Results show diurnal and annual trends of the forecast accuracy, especially for the 2m temperature. Stations located at mountain peaks, as well some close to mountain massifs were pointed out with worse forecasts in comparison to others. It was established that for peak stations, ALADIN-BG underestimates significantly the night temperatures. Further in-deep investigations will be performed to explain such strong night temperature underestimations, that could be due to model physics, surface, forecast interpolation or any other reason.

ACKNOWLEDGEMENT

Dr Rilka Valcheva during her work for the present paper was supported by National scientific program "Young scientists and postdoctoral students", project № CHR-04-7/28.02.2020.

REFERENCES

Courtier, P. and Geleyn, J.-F., (1988), A global numerical weather prediction model with variable resolution: Application to the shallow model equations, Q. J. Roy. Meteor. Soc., 114, 1321–1346.

Courtier, P., Freydier, C., Geleyn, J.-F., Rabier, F., and Rochas,M., (1991), The ARPEGE project at Météo-France, Proceedings of 1991 ECMWF Seminar on Numerical Methods in Atmospheric Mod-els, ECMWF, Reading, UK, 193–231.

Ebert E, McBride J., (2000), Verification of precipitation in weather systems: determination of systematic errors. J. Hydrol. 239 : 179-202.

Sun B, Yu L, Weller R., (2003), Comparisons of surface meteorology and turbulent heat fluxes over the Atlantic: NWP model analyses versus moored buoy observations. J. Clim. 16: 679–695.

Termonia, P., Fischer, C., Bazile, E., Bouyssel, F., Brožková, R., Bénard, P., Bochenek, B., Degrauwe , D., Derková, M., El Khatib, R., Hamdi, R., Mašek, J., Pottier, P., Pristov, N., Seity, Y., Smolíková, P., Španiel, O., Tudor, M., Wang, Y., Wittmann, C., Joly, A., (2018), The ALADIN System and its canonical model configurations AROME CY41T1 and ALARO CY40T1, Geosci. Model Dev., 11, 257–281.

Tsenova, B and Bogatchev, A., (2019), Some general results of the verification of meteoelements forecasted by ALADIN-BG and AROME-BG versus synoptical measurements in Bulgaria during 2018, ALADIN-HIRLAM Newsletter №12.

Appendix

Table 1. Monthly mean BIAS of the 72-hour forecast (based on the two model runs, at 06 and 18 UTC) for the year 2020 for 40 synoptic stations in Bulgaria from ALADIN-BG for 2 meter temperature (in ° C).

BIAS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Ahtopol	-0,41	-0,52	-0,76	-0,75	-0,20	-0,52	-0,44	-0,28
Blagoevgrad	2,02	0,83	0,42	1,11	2,43	1,84	1,64	2,21
Botev	-4,77	-2,42	-2,43	-2,34	-1,75	-1,16	-1,79	-1,94
Burgas	0,47	-0,20	-0,40	-0,93	-0,75	-0,94	-0,62	-0,30
Chernivr	-4,95	-2,21	0,41	-1,98	-1,29	-1,67	-2,29	-2,32
Chirpan	0,96	0,33	0,33	0,12	0,28	0,18	1,47	0,80
Dobrich	0,27	0,05	0,24	-0,52	-1,34	-1,21	-1,40	-1,71
Dragoman	0,09	0,14	-0,18	-0,09	0,70	0,27	0,74	0,73
Elhovo	-0,07	-0,47	-0,05	-0,15	0,11	0,17	0,42	0,27
Emine	-0,01	-0,42	-1,03	-1,58	-1,36	-1,77	-1,23	-0,91
Haskovo	-0,24	-0,09	0,12	-0,45	0,25	0,11	0,84	0,61
Kaliakra	0,07	-0,30	-0,69	-1,32	-1,19	-1,89	-0,94	-0,50
Kurjali	-0,35	-0,62	-0,29	-0,67	0,48	0,53	-0,63	-0,29
Karnobat	-0,49	-0,52	-0,35	-0,80	-0,62	-0,26	0,31	-0,50
Kazanluk	0,94	0,56	0,31	0,44	0,99	0,74	1,81	1,12
Kustendil	2,21	1,16	0,33	0,23	1,92	1,07	0,93	1,55
Kneja	1,24	0,83	0,43	0,97	0,86	0,41	1,41	1,00
Lom	-0,42	-0,35	-0,34	-0,15	0,16	-0,29	0,35	0,33
Lovech	0,13	-0,01	-0,40	0,34	0,71	0,08	0,90	0,97
Montana	-0,28	0,30	0,05	0,15	0,77	-0,15	-0,48	-0,64
Murgash	-3,36	-1,91	-2,12	-1,75	-1,36	-1,27	-1,59	-1,71
Musala	-4,32	-2,27	-2,28	-2,96	-1,98	-1,64	-3,01	-2,71
Novoselo	0,33	0,20	0,17	0,74	0,25	-0,35	0,05	0,25
Oriahovo	-0,05	-0,07	-0,28	-0,18	0,12	-0,12	0,75	0,85
Pazarjik	-0,18	-0,19	-0,03	-0,08	0,35	0,50	1,88	1,70
Pleven	0,21	0,19	0,28	0,83	0,97	0,69	1,83	-0,44
Plovdiv	-0,17	0,19	-0,13	0,02	0,47	0,66	1,95	1,73
Razgrad	-1,51	-1,25	-1,13	-1,54	-0,34	-1,10	-0,37	-0,62
Rojen	-2,49	-1,79	-1,25	-0,51	-0,73	-1,43	-2,08	-2,78
Ruse	0,20	-0,22	-0,37	-0,60	0,59	0,23	0,70	0,46
Sandanski	0,79	0,09	-0,08	0,20	1,42	1,34	1,31	1,46
Shabla	0,60	-0,10	-0,10	-0,23	-0,28	-0,42	-1,34	-0,73
Silistra	-0,22	-0,30	0,01	-0,13	0,05	0,02	0,78	0,40
Sliven	-0,51	-0,90	-0,55	-0,79	-0,27	-0,44	0,36	0,05

Sofia	2,15	1,39	0,79	0,61	0,89	0,68	0,77	1,01
Svishtov	0,81	0,27	0,25	-0,09	0,28	0,09	1,30	1,63
Varna	-0,41	-0,57	-0,38	-0,67	-0,29	-0,20	0,16	-0,32
Vturnovo	0,74	0,35	-0,36	0,07	0,76	0,62	0,60	1,21
Vidin	1,25	1,09	1,12	1,95	1,58	1,05	2,01	2,49
Vratsa	0,27	-0,48	-0,20	-0,53	-0,14	-0,42	-0,41	-0,16

Table 2. Monthly mean RMSE of the 72-hour forecast (based on the two model runs, at 06 and 18 UTC) for the year 2020 for 40 synoptic stations in Bulgaria from ALADIN-BG for 2 meter temperature (in ° C).

RMSE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Ahtopol	1,41	1,80	1,86	1,88	1,68	1,74	1,77	1,50
Blagoevgrad	3,52	2,49	2,32	2,54	3,26	2,52	2,44	2,88
Botev	5,82	3,88	3,12	3,28	2,96	2,02	2,48	2,65
Burgas	1,58	1,76	1,79	1,74	1,82	2,04	1,66	1,19
Chernivrh	6,03	3,70	1,58	3,32	2,63	2,42	2,91	3,03
Chirpan	3,11	2,27	1,83	1,85	1,88	2,17	2,32	2,05
Dobrich	2,27	1,74	1,88	2,25	2,27	2,25	2,19	2,29
Dragoman	2,51	2,42	2,55	2,03	1,88	1,73	1,91	2,15
Elhovo	2,13	1,96	1,81	1,83	2,01	2,15	1,61	1,73
Emine	1,35	1,67	2,09	2,52	2,31	2,42	1,99	1,74
Haskovo	2,04	1,91	1,77	1,85	1,79	1,95	1,87	1,96
Kaliakra	1,19	1,32	1,64	1,88	2,02	2,39	1,74	1,10
Kurjali	2,21	2,04	1,67	1,96	1,97	2,07	1,59	1,94
Karnobat	2,09	1,85	1,90	1,78	1,90	2,11	1,45	1,64
Kazanluk	3,22	2,79	2,35	2,51	2,16	2,37	2,65	2,56
Kustendil	3,92	2,90	2,28	2,37	3,14	2,14	2,02	2,41
Kneja	2,72	2,03	2,12	2,22	2,38	2,11	2,67	2,37
Lom	1,97	1,87	2,03	1,78	2,19	2,02	1,94	1,90
Lovech	1,94	1,75	2,00	1,72	2,05	1,94	2,03	2,16
Montana	2,04	2,02	2,14	1,93	2,30	1,93	1,81	2,11
Murgash	4,34	3,05	3,03	2,89	2,36	2,02	2,31	2,57
Musala	5,28	3,44	3,13	3,96	2,80	2,36	3,65	3,24
Novoselo	1,82	1,50	1,84	1,97	1,86	2,01	1,73	1,87
Oriahovo	2,31	1,84	2,20	1,88	2,00	1,96	2,42	2,19
Pazarjik	2,47	2,05	1,60	1,87	1,79	2,06	2,83	2,65
Pleven	1,86	1,79	1,89	1,72	2,20	2,17	2,70	2,04
Plovdiv	2,50	2,26	1,88	1,88	1,23	2,26	2,55	2,62
Razgrad	2,35	2,25	2,60	2,53	2,07	2,44	1,97	2,00
Rojen	3,37	3,12	2,23	1,32	2,53	2,35	2,72	3,31

Ruse	1,95	1,85	1,95	1,63	1,82	2,03	1,93	1,98
Sandanski	2,53	2,04	2,16	2,36	2,37	2,26	2,25	2,47
Shabla	2,06	1,73	1,52	1,54	1,76	1,66	1,88	1,53
Silistra	1,81	1,71	1,82	1,65	1,94	1,96	2,11	1,85
Sliven	2,27	1,90	1,87	1,95	1,57	1,86	1,46	1,75
Sofia	3,43	2,73	2,38	2,14	1,99	1,93	1,94	2,12
Svishtov	2,24	1,90	1,82	1,60	2,04	2,01	2,58	2,44
Varna	1,38	1,62	1,58	1,54	1,51	1,56	1,43	1,14
Vturnovo	2,29	2,02	2,39	1,92	2,05	2,11	2,01	2,55
Vidin	3,10	2,80	2,47	3,11	2,64	2,30	2,74	3,27
Vratsa	2,02	2,16	2,27	2,00	2,25	1,83	1,92	1,77