Report for RC LACE

Verification of ALARO 3MT on 4.4km resolution

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1. Introduction

The ALARO physics including 3MT is, at the moment, operationally used already in 3 countries (CZ, SI, SK). These models are running at scales around 10 km mesh-size. ALARO physics can be used also on higher resolutions where model performance still has to be evaluated/validated. For this purpose, the model at 4.4 km resolution is in parallel run in Slovenia since the end of July 2008 and a database with one year of simulations for the whole of 2007 has been created.

This reports intends to give a first contribution to evaluate the skill of the precipitation forecasts for the slovenian territory. The model performance is evaluated in terms of accuracy and skill in the view of NWP. Classic statistics and scores for chosen precipitation classes for one year data were calculated, using a 24 hour period accumulation. The calculations were made in the user-oriented verification framework, using the nearest integration point. This implies that for such a high resolution model, the double penalty issue [1] may cause worse scores.

In verification, the statistics or scores used tend to vary with the purpose of the task. There is no full agreement on the statistics or scores that should be used and each meteorological service tend to apply their own methodology, although some common approach is widely used [2]. In this way and in the light of the ECMWF recommendations [3] for statistics and scores to obtain, for this report calculations were made of Proportion Correct (PC) or Accuracy (ACC), Heidke Skill Score (HSS), Pierce Skill Score (PSS), Bias, Probability of Detection (POD), False Alarm Ratio (FAR), False Alarm Rate (F), Critical Success Index (CSI) and Equitable Threat Score (ETS).

There are ongoing investigations for verification with scale dependent techniques and spatial structures measurements [1], which are not addressed in this report but should be considered in future works.

2 . Data description

During Summer 2008 ALARO forecasts were computed for the whole year of 2007. The forecast characteristics were 4.4 km resolution, 200s time step, 43 vertical levels, coupling with ARPEGE every 3 hours, 30 hours integration starting from 00 UTC, initialization off all water species except the vapor with 0 and no DFI. From these, 24 hours accumulated precipitations were computed, from h+06 till h+30, summing all four types of surface precipitation to obtain the daily total precipitation.

For observations one used the climatological stations network of Environmental Agency of Slovenia (EARS), of which 38 stations had one full year of available data. The distribution of stations over Slovenia can be seen on figure 1.

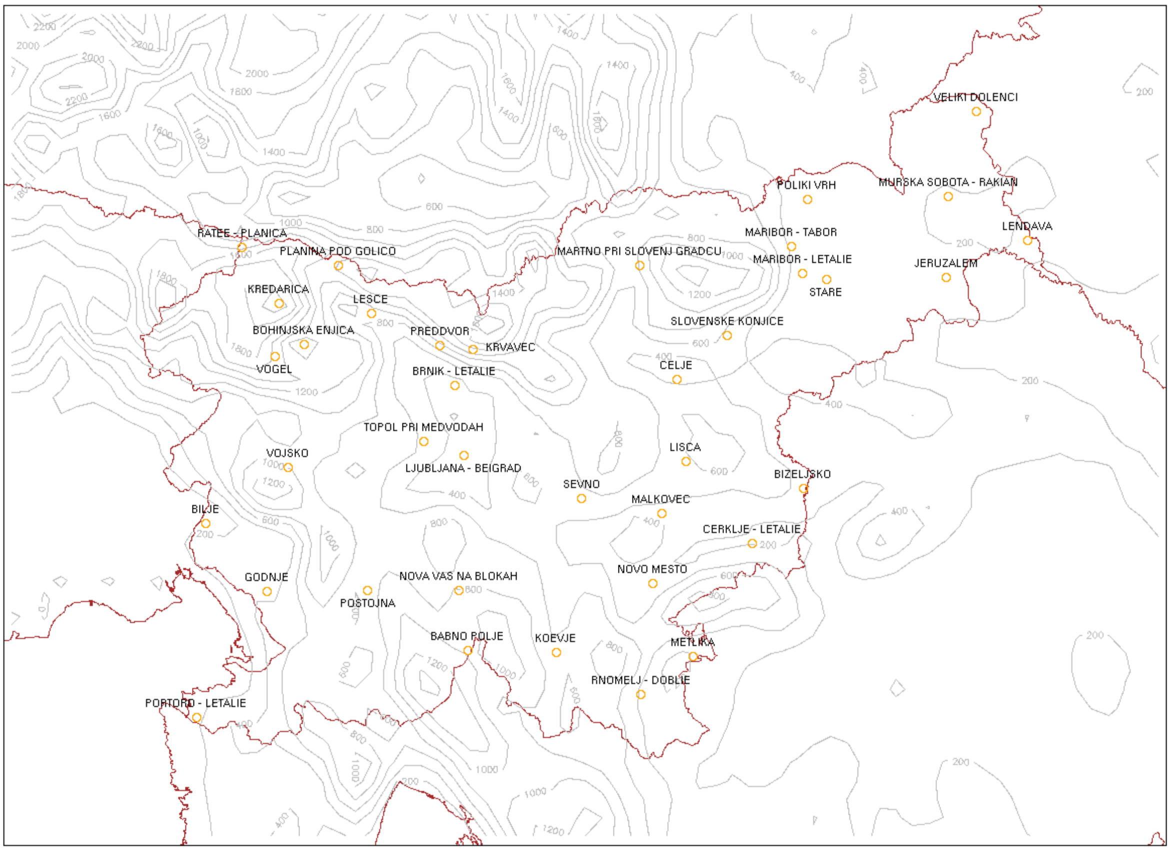

Figure 1 – Location of the climatological observation stations plotted over the model's orography.

3. Procedures and results

All calculations and figures were made with R software, using the Rfa package for reading the FA files. In the figures created for sub-chapter 3.2, the color legend was forced to keep the same values so that the precipitation values would be represented by the same colors, with dark blue indicating any values below 3 mm and red indicating any values above 160 mm. In the figures created for the Annexes, the same earlier procedure was followed but for these cases dark blue indicates any values below 10 mm and red indicates any values above 1000 mm.

The first maps were made by plotting precipitation of the whole domain for the yearly values as well as for the monthly values. All maps showed unrealistic features along the borders of the domain in the areas of ARPEGE influence, specially in the south border. Those were probably caused by a disagreement between ARPEGE and ALARO wind fields, with possible convection induced by convergence of wind.

Yearly precipitation amounts and distribution over Slovenia is realistic. At the moment the analysis based on observations is not yet available so comparison will be done later.

The values of precipitation for the year of 2007 are shown in figure 2 for the whole domain and in figure 3 for a zoom over Slovenia. The values of monthly precipitation are shown as thumbnails in Annex A and in Annex B there are thumbnails with zooms for Slovenia of the maps of Annex A.

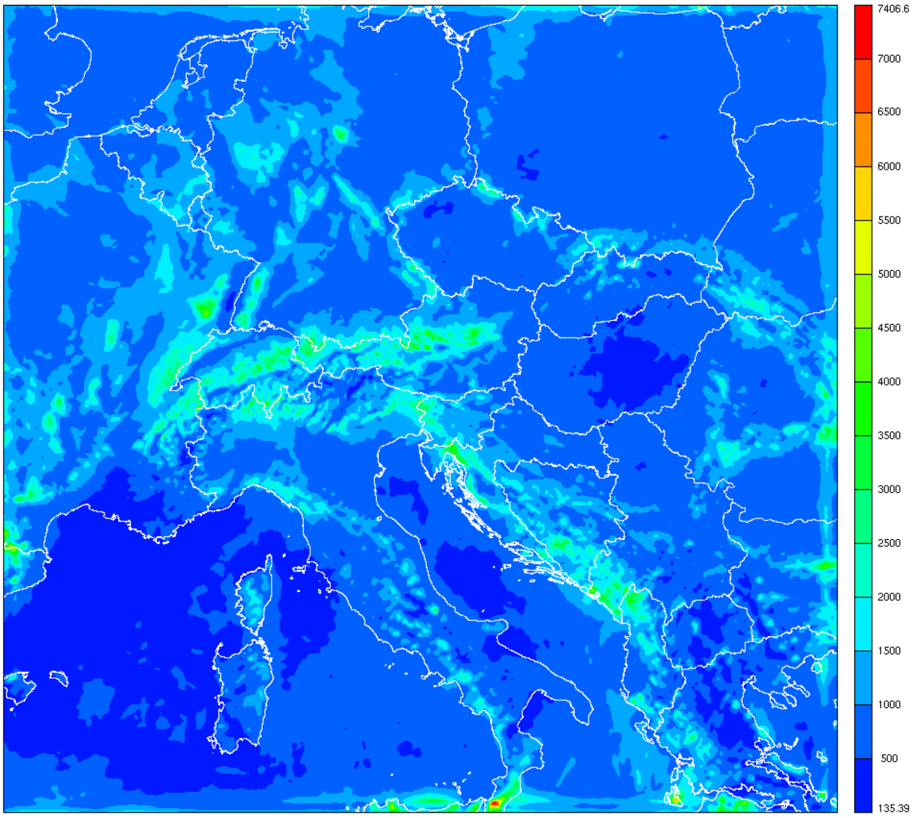

Figure 2 – Total accumulated precipitation for 2007.

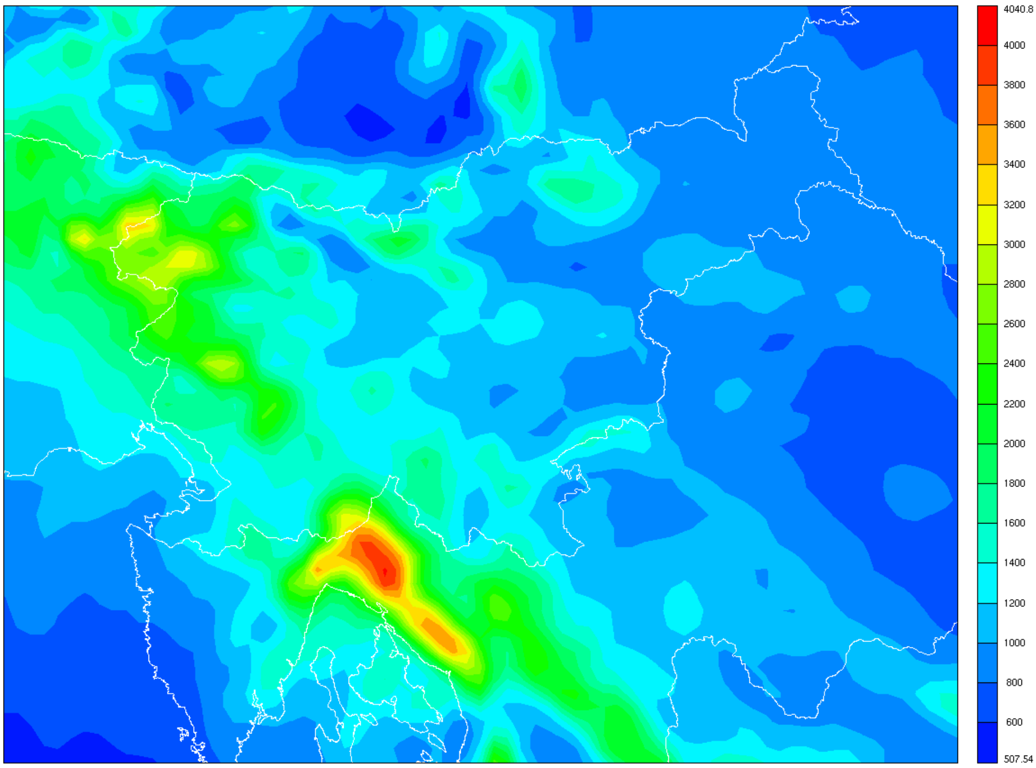

Figure 3 – Zoom over Slovenia of total accumulated precipitation for 2007.

3.1 Objective verification

For this work the point verification methodology was used, choosing the nearest integration point to the observation site. Since inside Slovenia there are several areas of complex orography, the nearest point blindly chosen could result in using a model point located in a different slope of the observation point, despite the high resolution of the model. Visual inspection for the location of the stations against the nearest model integration points was made for those areas, using figure 4, mostly not finding any relevant differences.

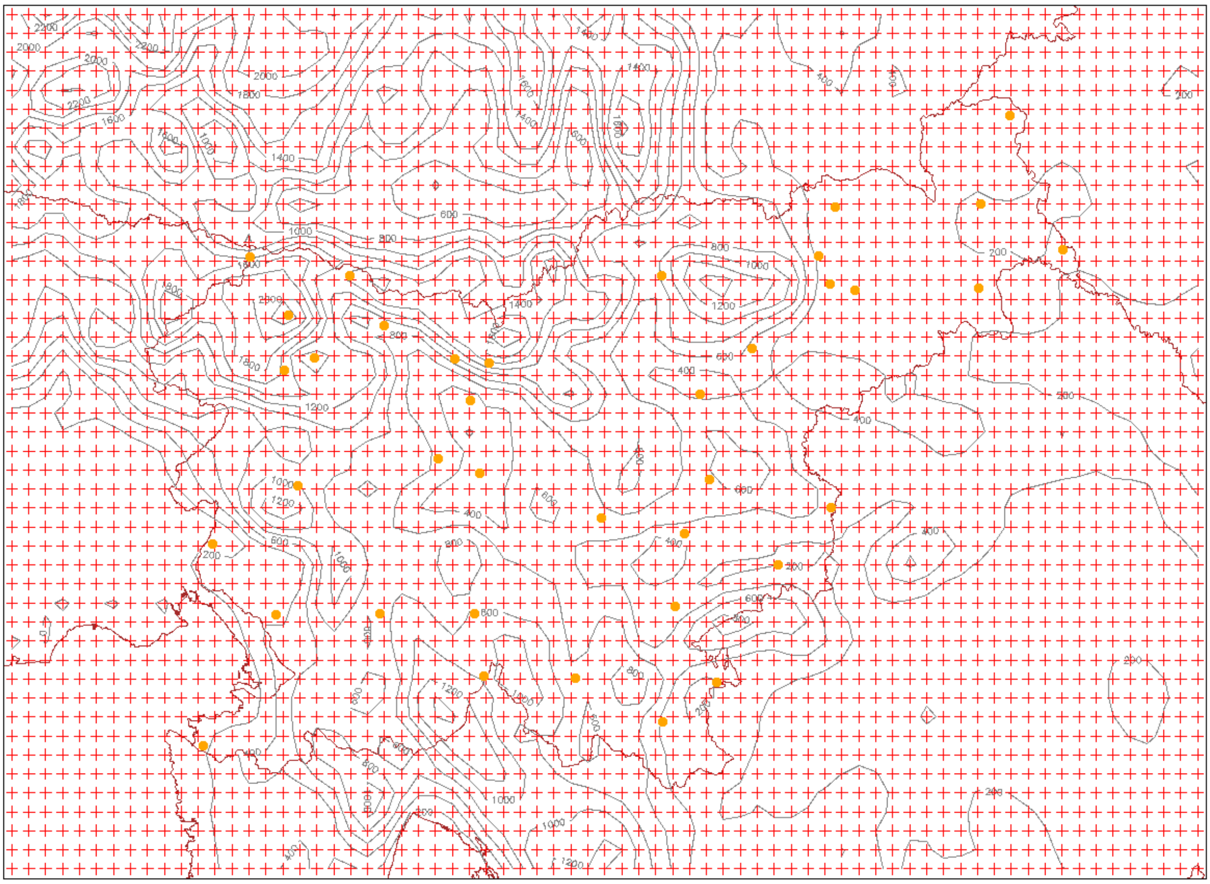

Figure 4 – Model grid points, observations stations and model orography.

The first procedure for objective verification was to build a multi-category contingency table. General results can mask forecast performance so a stratification of data into classes was done. The classes were chosen in accordance with other verification procedures in LACE countries. The obtained contingency table constitutes table 1.

Table 1 – Contingency table for one year data of 38 climatological stations.

Fcs/Obs	0.0 – 0.2	0.2 – 3.0	3.0 – 10.0	10.0 – 20.0	20.0 –	Total Fcs
0.0 – 0.2	7285	696	139	29	8	8157
0.2 – 3.0	1341	792	383	93	28	2637
3.0 – 10.0	322	393	512	217	97	1541
10.0 – 20.0	28	113	287	265	186	879
20.0 –	13	18	101	171	353	656
Total Obs	8989	2012	1422	775	672	13870

The general results obtained for 2007, written in table 2, show some skill for ALARO 4.4km, with relatively high values of around 0.4 for HSS and PSS. The result of 0.66 for PC is just median. PC values are very influenced by the most common class, which in general is the non-precipitating one. As models often have good results in distinguishing between rain or no rain cases, PC values can be quite high. In this case, the non precipitation class has lesser weight, reflecting in lower PC values.

Table 2 – Statistics and scores of multi-category forecasts.

Stats/Scores	Value
PC or ACC	0.66
HSS	0.41
PSS	0.40

Statistics and skill values for each precipitation class were calculated and put together in table 3. Analyzing that table, focus should be put on the interesting results obtained for the class of more than 20 mm forecast. The bias was almost 1 and CSI and ETS scores were relatively good. But opposing this results, the POD is low and the FAR is rather high.

The non-precipitation class shows good results. The ability to forecast the event as rain or as no rain is good, but the value of false alarm rate (F) is not so low, indicating that in 18% of the cases that the model forecast no precipitation there was precipitation observed.

All of the three middle classes show similar scores, so a general interpretation of the results for them can be done. All classes are over-forecast as seen by the bias value greater than one. That contributes to the very high FAR obtained. In contrast, low POD values were obtained, indicating that less than 40% of the situations are correctly forecast. CSI and ETS values are low, confirming that poor forecasts were made for these classes.

Table 3 – Statistics and scores for one year data for each precipitation class

Stats/Scores	0.0 – 0.2	0.2 – 3.0	3.0 – 10.0	10.0 – 20.0	20.0 –
Bias	0.91	1.31	1.08	1.13	0.98
POD	0.81	0.39	0.36	0.34	0.53
FAR	0.11	0.70	0.67	0.70	0.46
F	0.18	0.16	0.08	0.05	0.02
CSI	0.74	0.21	0.21	0.19	0.36
ETS	0.44	0.12	0.15	0.16	0.34

For each of the 38 stations, general scores were calculated. In Annex 3, table 10 summarizes PC, HSS e PSS scores for all classes. In searching for a better understanding of the model performance, an inside look of the results for the stations with the best and worst scores is made next.

The best results, according to HSS values for individual stations, were obtained with the station of Postojna, located in the south west-region of Slovenia.

Table 4 – Contingency table of Postojna station

Fcs/Obs	0.0 – 0.2	0.2 – 3.0	3.0 – 10.0	10.0 – 20.0	20.0 –	Total Fcs
0.0 – 0.2	194	10	1	0	0	205
0.2 – 3.0	29	27	9	2	0	67
3.0 – 10.0	11	14	15	4	5	49
10.0 – 20.0	0	4	3	7	4	18
20.0 –	2	0	6	6	12	26
Total Obs	236	55	34	19	21	365

Table 5 – Statistic and scores of multi-category forecasts for Postojna station

Stats/Scores	Value
PC or ACC	0.70
HSS	0.49
PSS	0.46

Table 6 – Statistics and scores of Postojna station for each class

Stats/Scores	0.0 – 0.2	0.2 – 3.0	3.0 – 10.0	10.0 – 20.0	20.0 –
Bias	0.87	1.22	1.44	0.95	1.24
POD	0.82	0.49	0.44	0.37	0.57
FAR	0.05	0.60	0.69	0.61	0.54
F	0.09	0.13	0.10	0.03	0.04
CSI	0.79	0.28	0.22	0.23	0.34
ETS	0.54	0.20	0.16	0.21	0.31

In this station, the distribution of precipitation by classes shown in table 4 has similar relative values as the ones for the whole country. Comparatively, slighter better results were obtained in all classes except for the class of more than 20 mm, where the model had lower performance. In general, the results are very similar, reflecting the similarity in the contingency tables. It should be mentioned the clear misses in two situations were the model forecast more then 20 mm but no precipitation was observed.

The worst scores were obtained for the station of Krvavec, located in north area of Slovenia at a height of 1740 meters, at the southern slope of the eastern Alps.

Table 7 – Contingency table of Krvavec station

Fcs/Obs	0.0 – 0.2	0.2 – 3.0	3.0 – 10.0	10.0 – 20.0	20.0 –	Total Fcs
0.0 – 0.2	145	15	3	0	0	163
0.2 – 3.0	49	27	11	1	1	89
3.0 – 10.0	20	12	14	8	1	55
10.0 – 20.0	1	5	14	9	2	31
20.0 –	0	1	8	10	8	27
Total Obs	215	60	50	28	12	365

Table 8 – Statistic and scores of multi-category forecasts for Krvavec station

Stats/Scores	Value
PC or ACC	0.56
HSS	0.33
PSS	0.32

Table 9 – Statistics and scores of Krvavec station for each class

Stats/Scores	0.0 – 0.2	0.2 – 3.0	3.0 – 10.0	10.0 – 20.0	20.0 –
Bias	0.76	1.48	1.10	1.11	2.25
POD	0.67	0.45	0.28	0.32	0.67
FAR	0.11	0.70	0.75	0.71	0.70
F	0.12	0.20	0.13	0.07	0.05
CSI	0.62	0.22	0.15	0.18	0.26
ETS	0.36	0.12	0.08	0.14	0.24

The non-precipitating class results are not so good at Krvavec, lowering the overall skill values for the station. The three classes between 0.2 mm and 20.0 mm have poor results, with low POD and high FAR values. The ETS, a more fair score to use, shows very low results, indicating a poor performance by the model in those classes. The class of more than 20 mm here has a very high bias and the corresponding over-forecasting resulted in higher POD and higher FAR.

3.2 Subjective verification

Precipitation patterns can be correct but misplaced in space and time, resulting in low scores for point-verification techniques. By using 24 hour precipitation accumulation some filtering of incorrect temporal forecast is implicitly performed. For spatial patterns, a subjective verification with visual checking will be also used.

Several individual cases were chosen based on the values of observed precipitation and they were grouped, whenever possible, as representing typical synoptic situations that occur in Slovenia. The synoptic cases were identified as:

A: Cold front
B: South-western flow
C: Cyclones
D: Convection

Situations representing typical behavior of the model for each case are plotted next and a subjective evaluation is made. In the end, a special case that would not fit in the synoptic situations above is also shown.

Each of the following figures have represented 24 hours accumulated observed precipitations from 06 UTC of previous day till 06 UTC of present day, marked with a circle over the 24 hours forecast accumulated precipitation field. Each circle represents a station with the measured value of precipitation in mm next to it and filled with a color that corresponds to the interval of the color scale.

3.2.1 Evaluation for front passing cases

The cases identified as a cold front passing have a south-west flow associated at the surface and typical rain bands aligned in a south-west to north-east direction.

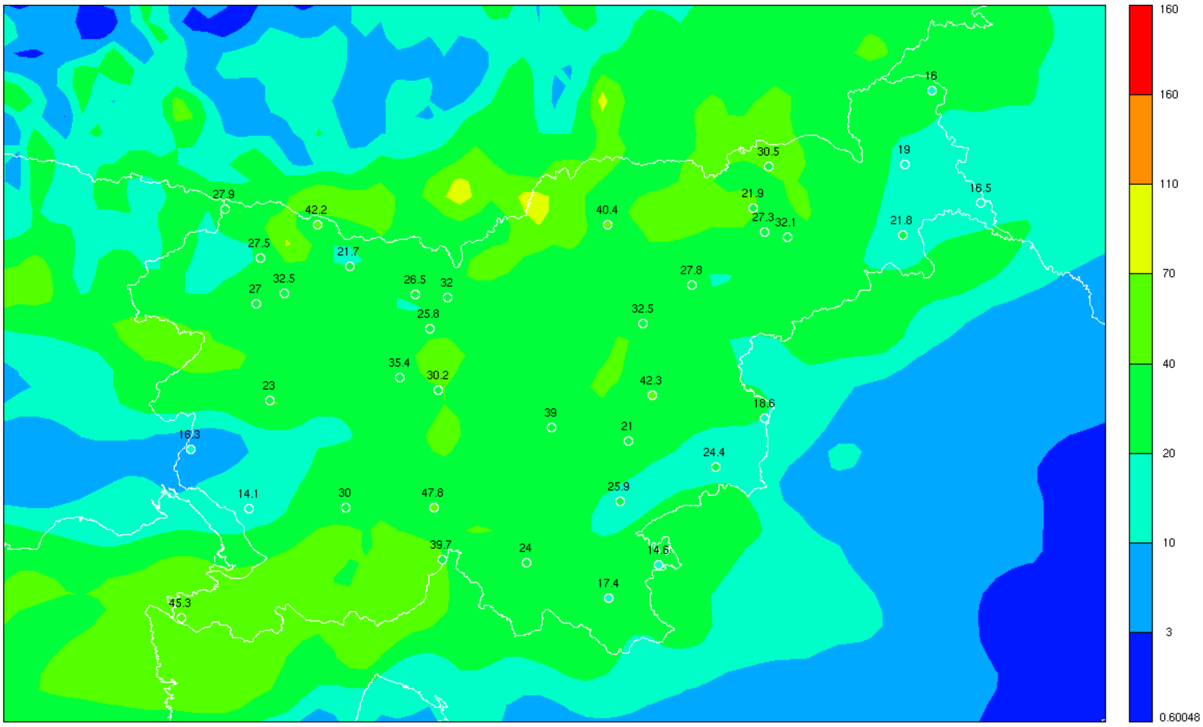

Figure 5 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 3rd September.

In the case of 3rd September, a good forecast was made, with the spatial pattern correctly predicted by the model and the values forecast close, in general, to the values observed.

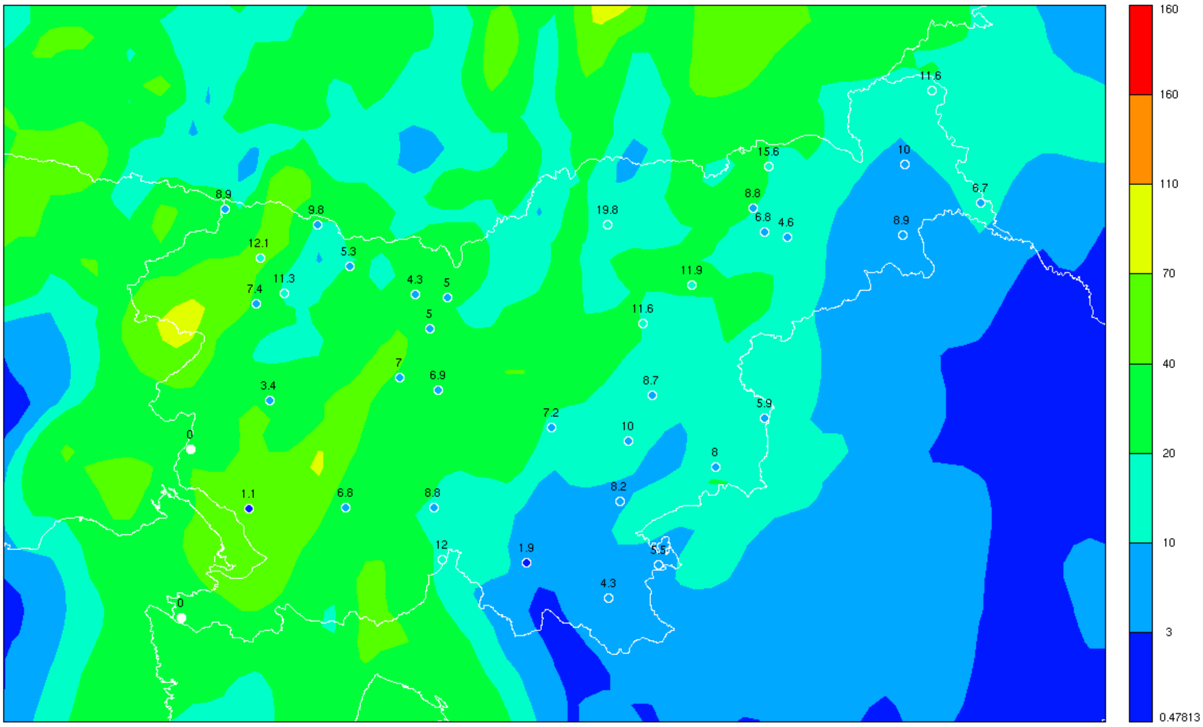

Figure 6 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 15th May.

For this situation, very poor forecast was made by the model with a wrong precipitation pattern, in which the higher values were forecast for areas where the lower values occurred. In general, heavy over-forecasting of precipitation values were made for this day.

Other cases not shown here indicate a dual behavior of the model, with the number of good and bad forecasts equaling each other for this synoptic situation.

3.2.2 Evaluation for south-west flow cases

In Slovenia, orographic precipitation contributes significantly to the total sum of yearly precipitation. In its more general form, winds coming from southwest reaching the Alps trigger the orographic convection. This situation has often been observed as lasting for several days.

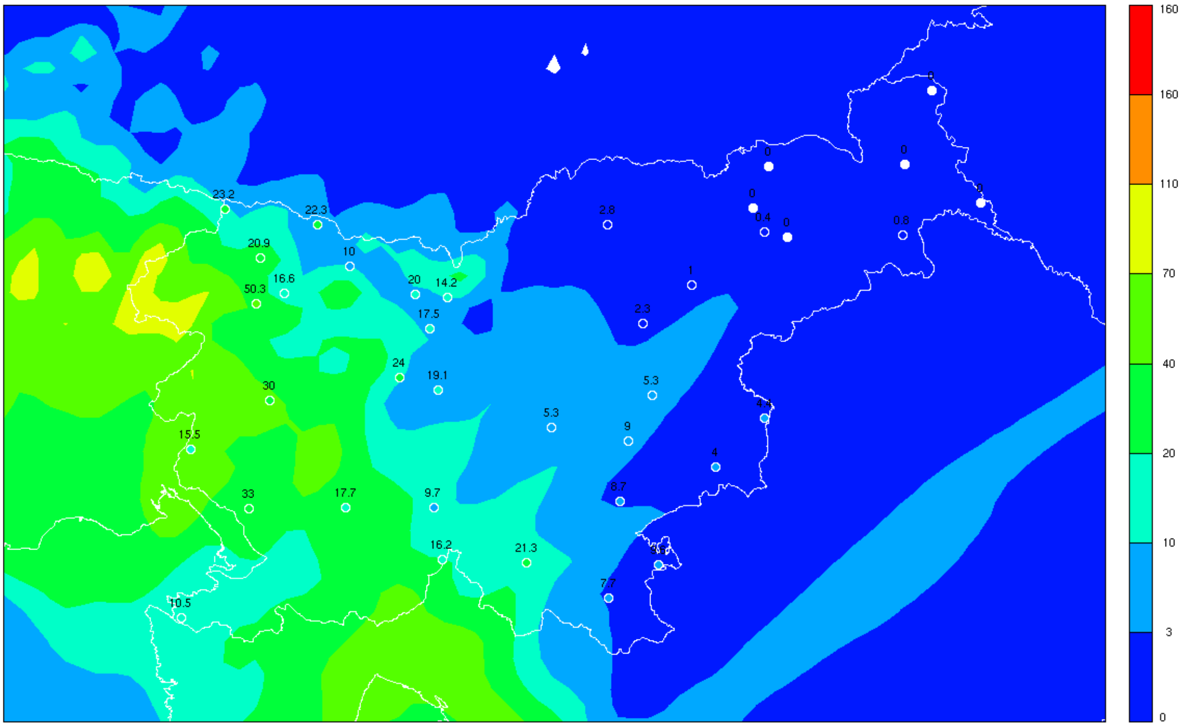

Figure 7 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 24th November.

Figure 7 reflects well the orographic precipitation in the north-west, most of west and south regions of Slovenia, with the higher forecast values following the orography. In the low areas of Italy and in part of west Slovenia, some other mechanism justifies the precipitation values forecast. As expected in this synoptic situation, none or very few rain was observed in the east and north-east part of the country, with ALARO being able to lower forecast values for the area but unable to give a no rain forecast in north-east regions. In general, a correct assessment of the meteorological situation was achieved by the model but with relevant discrepancies in some of values.

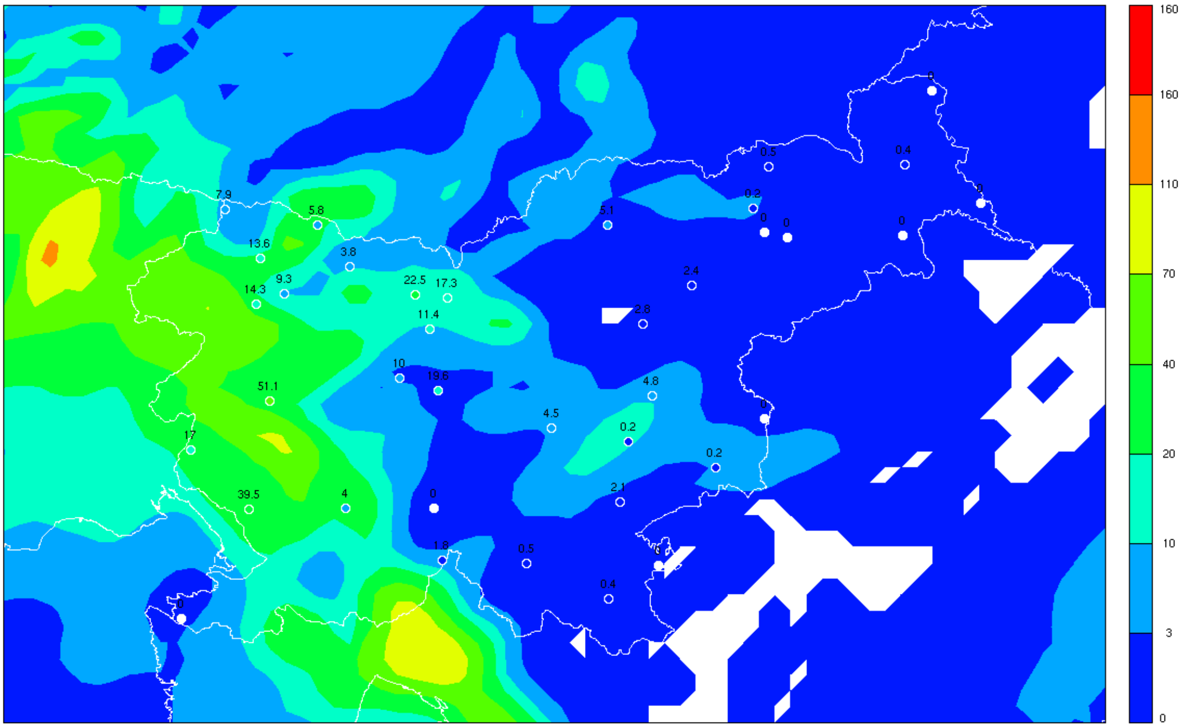

Figure 8 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 15th June.

For the 15th June, again the model was able to give a rain pattern associated with the higher orography of the region. But in this case, the rain pattern shows much too spreading over the north-west mountains, with some stations indicating heavy over-forecasting by the model. The rest of the country has a correct pattern with the exception of the areas in the center represented by Ljubljana and Malkovec stations, one with overestimation and the other with underestimation.

In general, the cases of south-west flow visually inspected showed good to medium agreement of forecasts patterns with the observations.

3.2.3 Evaluation for cyclone cases

One of the synoptic situations characterized was the passing of cyclones, associated with distributed precipitation all over the country.

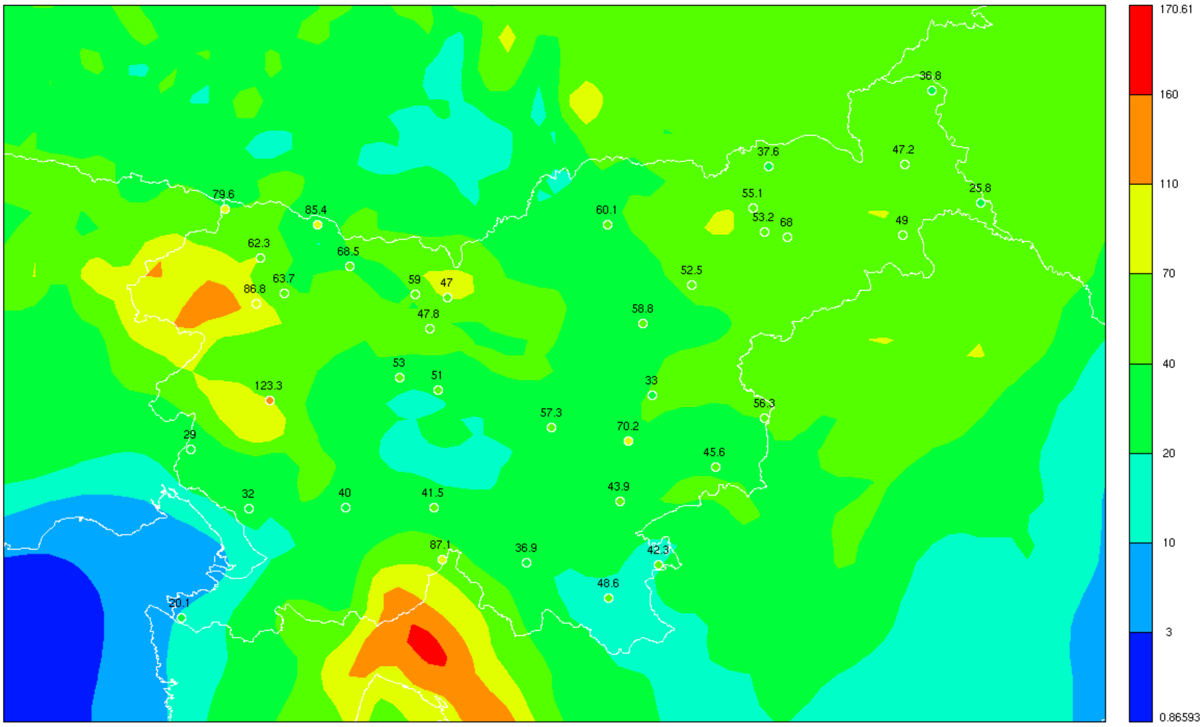

Figure 9 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 19th March.

The 19th March forecast had a general good agreement of the spatial pattern in the north, north-east and east of Slovenia. In the north-west, the stronger signal indicated by observations was forecast but with mismatches in some stations. Another stronger signal in the south was also forecast, with the observation in Babno polje station backing up the forecast. For the center and east regions under-forecasting occurred and the spatial pattern wasn't well represented.

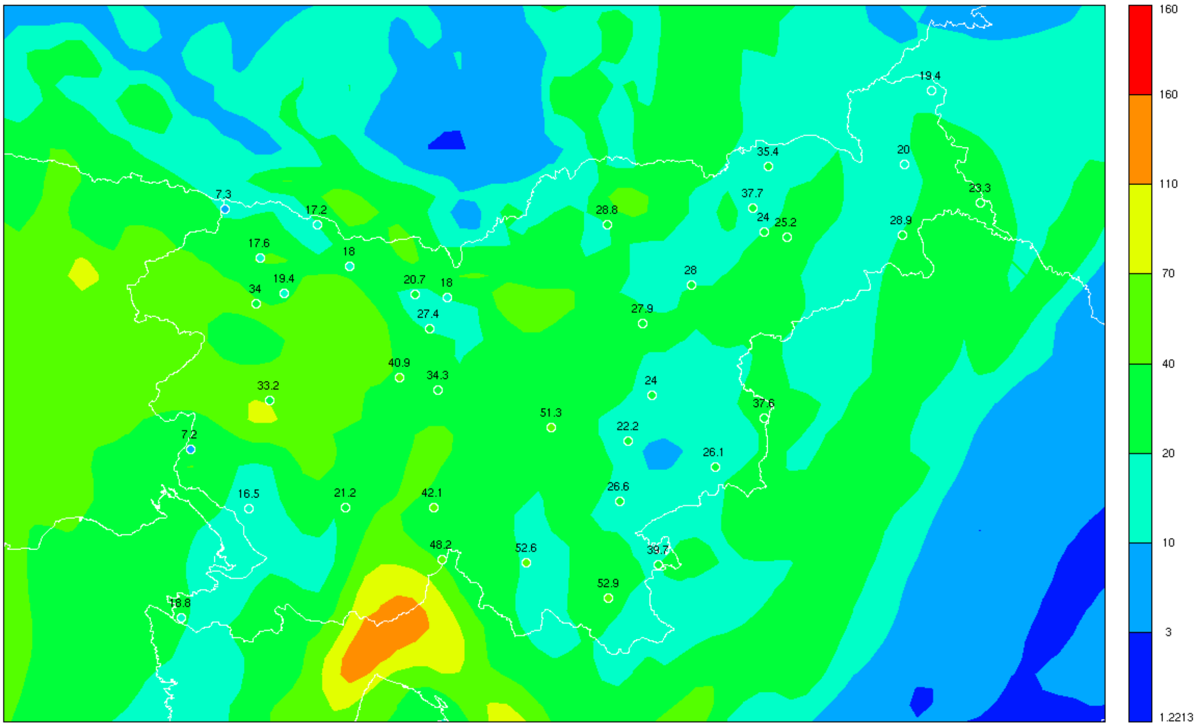

Figure 10 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 4th May.

In the case of 4th May the spatial pattern has a poor fit with the observations. In general, the precipitation observations show the country divided in two, with over-forecasting on the west and under-forecasting on the east.

The cyclone cases evaluated didn't manage to correctly forecast precipitation patterns for the whole country or didn't manage to give a correct forecast at all. Of the synoptic situations evaluated this was the one with the weaker results.

3.2.4 Evaluation for convection situations

The convective situations analyzed here were considered to be originated by upper lows.

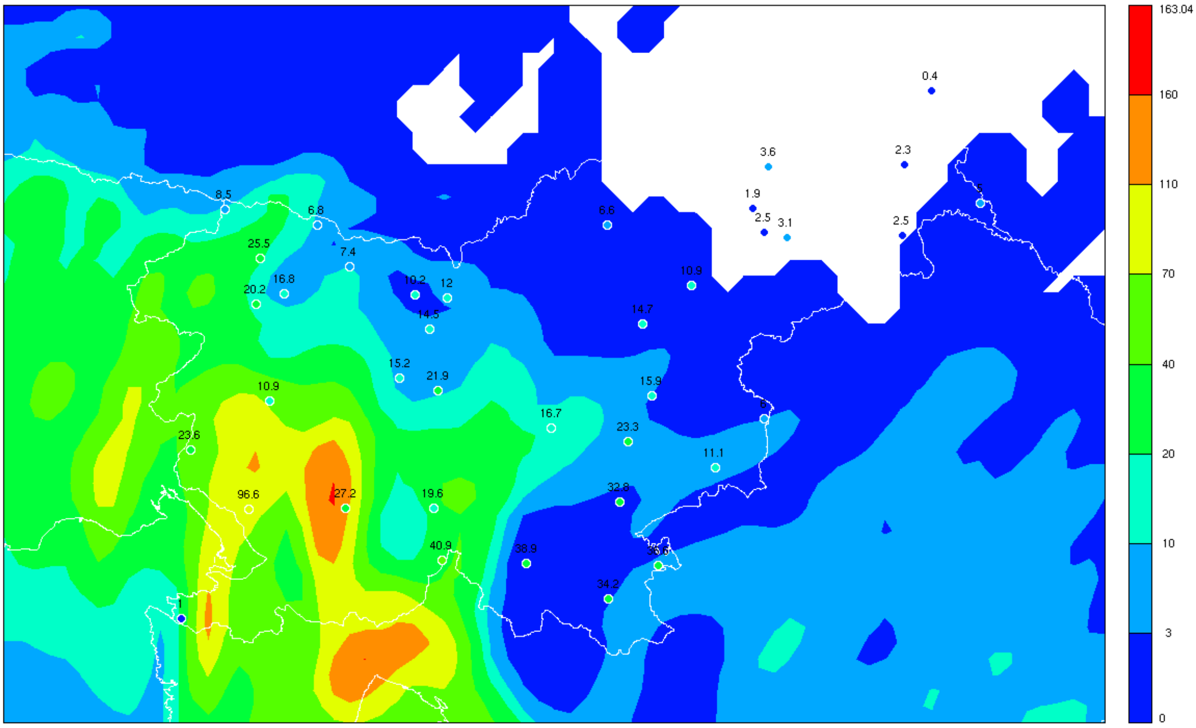

Figure 11 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 27th May.

Localized very high precipitation values were forecast, only matching the observations in Godnje and Babno polje stations. Other stations in the west of the country show heavy over-forecasting. In the south, several stations reported accumulated precipitations over 30 mm but the model barely forecast rain for the area.

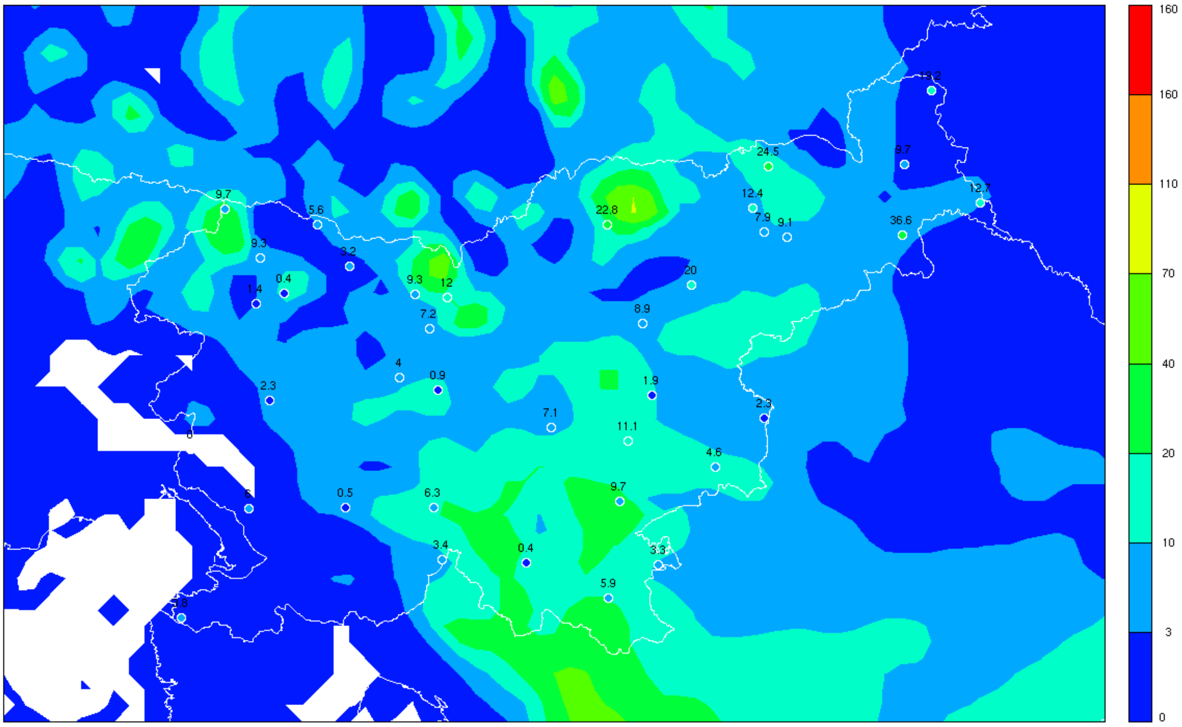

Figure 12 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 4th June.

The forecast for this case shows a clear convective precipitation pattern with various maximums distributed over several areas. In general, the model was unable to localize correctly the precipitation and to give approximate values to the ones observed.

Summarizing for all cases evaluated, the convective situations were not well forecast by the model, with some correct hits balanced by misses, the latest occurring more frequently specially if higher values of precipitation were observed.

3.2.5 Evaluation for the 18th September case

At the 18th of September 2007, high precipitation values were registered in the majority of slovenian territory, with very strong precipitations observed in the north and north-west of Slovenia.

The forecast of ALARO 3MT 4.4km shows for the north area of Slovenia, from west to east, a medium agreement of the spatial pattern, although with severe under-forecasting. The stronger signal in the north-west was well identified, but the other even stronger signal forecast for the south was not observed. Forecast precipitation for this extreme event was in general heavily underestimated by the model.

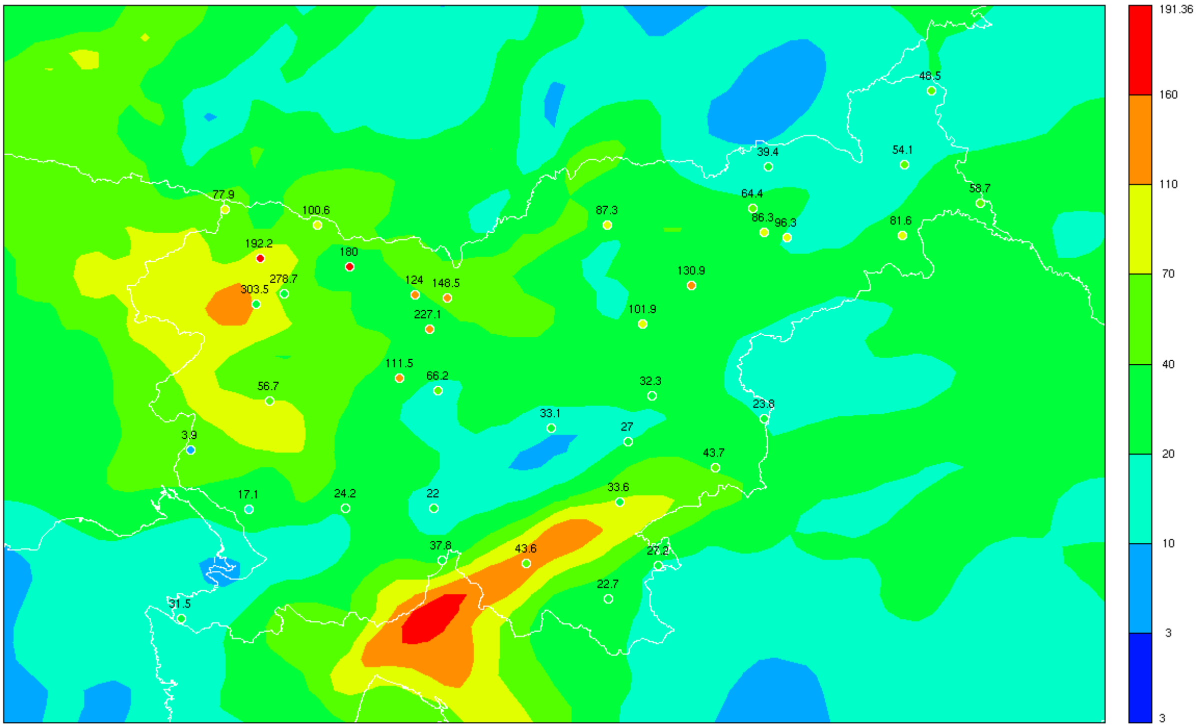

Figure 13 – 24h accumulation in mm of precipitation observations plotted over the forecast field for the 18th September 2007.

4. Conclusions and future work

For this report the scores for the precipitation forecasts by ALARO 3MT at 4.4 km resolution in Slovenia were calculated. One year data of forecasts for 2007 and observations from 38 climatological station over Slovenia were used as the dataset for the verification.

General results showed some skill for ALARO, with relatively high values of around 0.4 for HSS and PSS. The stratification of data in threshold classes revealed above average results for precipitation over 20 mm and poor results for classes 0.2mm to 3 mm, 3 mm to 10 mm and 10 mm to 20 mm.

In the subjective verification, four typical synoptic situations were chosen for evaluation and identified as cold front cases, south-west flow cases, cyclones cases and convection cases. ALARO managed to give good results in south-west flow cases, but for cold fronts it had a dual behavior with good and bad forecasts equaling each other in numbers. For convection cases, the model misses were superior to the model hits, which is not surprising given the inherent poor predictability of the location of separate convective storms. For cyclonic cases the global results were poor. It was therefore noticed that there are pertaining difficulties in forecasting very high precipitations in all synoptic situations.

To improve the understanding of the model performance, other stratification of data should be done with the separation of the dataset in seasons and in regions, emphasizing mountain areas versus low areas.

The use of fuzzy methodology [1], already tested in other ALADIN countries like Poland and France [4], or the use of scale decomposition methods [1] should be addressed in future works.

References

[1] WWRP/WGNE Joint Working Group on Verification, “Forecast Verification - Issues, Methods and FAQ”.
http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/verif_web_page.html

[2] WWRP/WGNE Joint Working Group on Verification, “Recommendations for the verification and intercomparison of QPFs from operational NWP models”. December 2004.
http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/WGNE/QPF_verif_recomm.pdf

[3] Pertti Nurmi, “Recommendations on the verification of local weather forecasts (at ECMWF member states)” , consultancy report to ECMWF Operations Department by Pertti Nurmi, October 2003.
http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/Rec_FIN_Oct.pdf

[4] Clive Wilson, “Review of verification activities and developments”, 30th EWGLAM/15th SRNWP meetings – Madrid 6-9 October 2008.
http://srnwp.met.hu/Annual_Meetings/2008/download/oct6/afternoon/EWGLAM_SRNWP_ET_verif.pdf

Annex 1 – Monthly precipitation maps for 2007

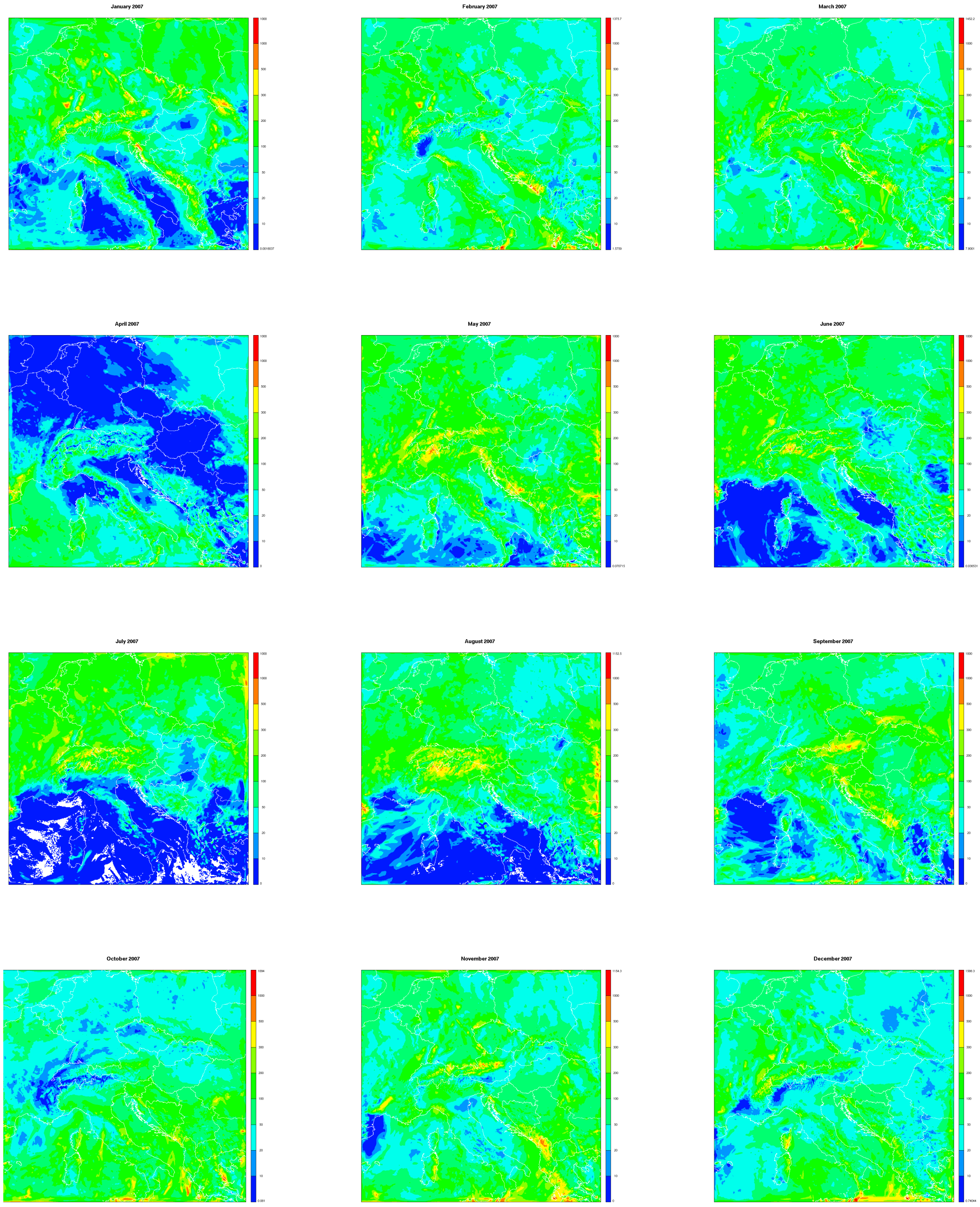

Figure 14 – Thumbnails of 2007 monthly precipitation.

Annex 2 – Monthly precipitation maps for 2007 zoomed over Slovenia

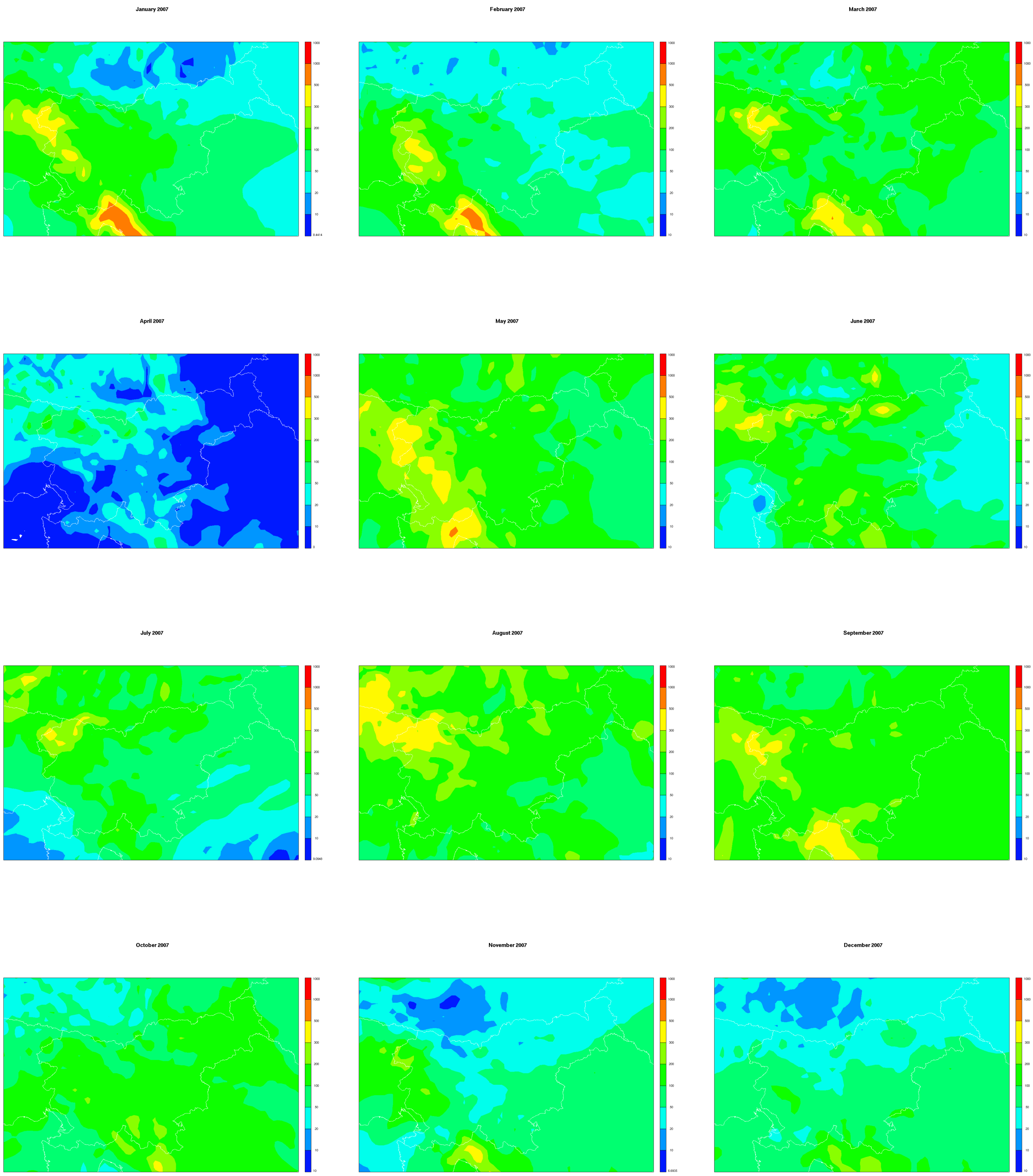

Figure 15 – Thumbnails of 2007 monthly precipitation over Slovenia.

Annex 3 – Scores for individual stations of EARS climatological network

Table 10 – Multi-class PC, HSS e PSS scores.

Station	PC	HSS	PSS
Krvavec	0.56	0.33	0.32
Brnik – Letalie	0.69	0.42	0.40
Preddvor	0.67	0.42	0.41
Planina Pod Golico	0.65	0.41	0.39
Kredarica	0.56	0.38	0.37
Ratee	0.64	0.42	0.39
Vojsko	0.59	0.37	0.34
Bilje	0.68	0.39	0.38
Godnje	0.68	0.40	0.39
Postojna	0.70	0.49	0.46
Nova Vas na Blokah	0.62	0.35	0.33
Babno Polje	0.62	0.40	0.38
Koevje	0.64	0.42	0.40
Topol Pri Medvodah	0.67	0.42	0.40
Ljubljana – Beigrad	0.65	0.38	0.37
Sevno	0.67	0.43	0.43
Bizeljsko	0.68	0.43	0.42
Malkovec	0.68	0.43	0.41
Novo Mesto	0.68	0.44	0.44
Rnomelj – Doblie	0.65	0.41	0.40
Celje	0.71	0.46	0.46
Slovenske Konjice	0.65	0.36	0.36
Stare	0.70	0.42	0.43
Maribor – Tabor	0.67	0.40	0.39
Maribor – Letalie	0.67	0.39	0.38
Martno Pri Slovenj Gradcu	0.67	0.41	0.41
Poliki Vrh	0.69	0.42	0.41
Jeruzalem	0.72	0.47	0.47
Lendava	0.72	0.44	0.41
Murska Sobota – Rakian	0.71	0.45	0.44
Veliki Dolenci	0.68	0.38	0.36

Station	**PC**	**HSS**	**PSS**
Lesce	0.68	0.45	0.43
Metlika	0.67	0.42	0.41
Vogel	0.57	0.36	0.34
Lisca	0.66	0.41	0.40
Portoro - Letalie	0.75	0.44	0.40
Bohinjksa Enjica	0.63	0.40	0.38
Cerklje – Letalie	0.70	0.45	0.44