LACE
nwp central europe

Assimilation of SYNOP and SEVIRI data

report from LACE stay in Budapest, 4/10/07-17/11/07

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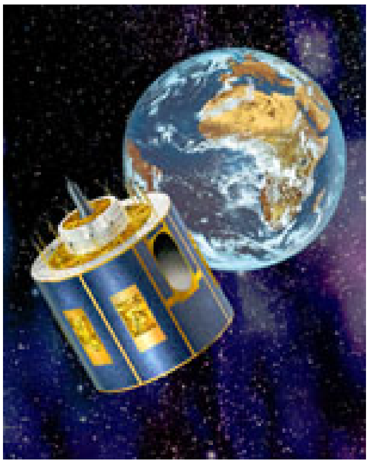

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1 Introduction

Different impact of SEVIRI data depending on the parameters and model levels was examined and overall impact of SEVIRI was found to be similar to that of ATOVS, AMDAR and AMV assimilated in high resolution in previous studies (Trojáková and Májek (2006) and Trojáková (2007)). So far these studies did not bring a clear guideline of an operational use of SEVIRI data in ALADIN/HU 3DVAR system. SEVIRI data are currently involved in screening, but excluded from minimization. There remained a few items to study: verification of precipitation or evaluation of impact over local domain of interest and usage of SEVIRI data together with SYNOP observation, which were not performed due to lack of time. There are consideration that usage of SYNOP observation can be dangerous because of presently used background error structure functions, which propagates low level increments too much to the high troposphere. This could be avoided either by using SYNOP together with SEVIRI which acts mostly in the altitude (as operational in Météo France) or by using more appropriate vertical correlation function in B matrix. An investigation of SYNOP observation behavior and an interaction with SEVIRI data on a case study is main interest of this study. This report is organized as follows: in Section 2 the case study and its findings are described. In Section 3 longer period results are evaluated and in the last section conclusions are drawn.

2 Case study

For simplicity we have focused on the same period from 20060826 till 20060923 as used in our previous studies. There prevailed summer anti-cyclonic weather with only a few periods with precipitation (all together 7 days with daily precipitation bigger than 10 mm over Hungary). For this study we have chosen case of August 29th, when the weather in large part of Europe was influenced by pressure-low (Fig. 1) and a cold front was passing Hungary.

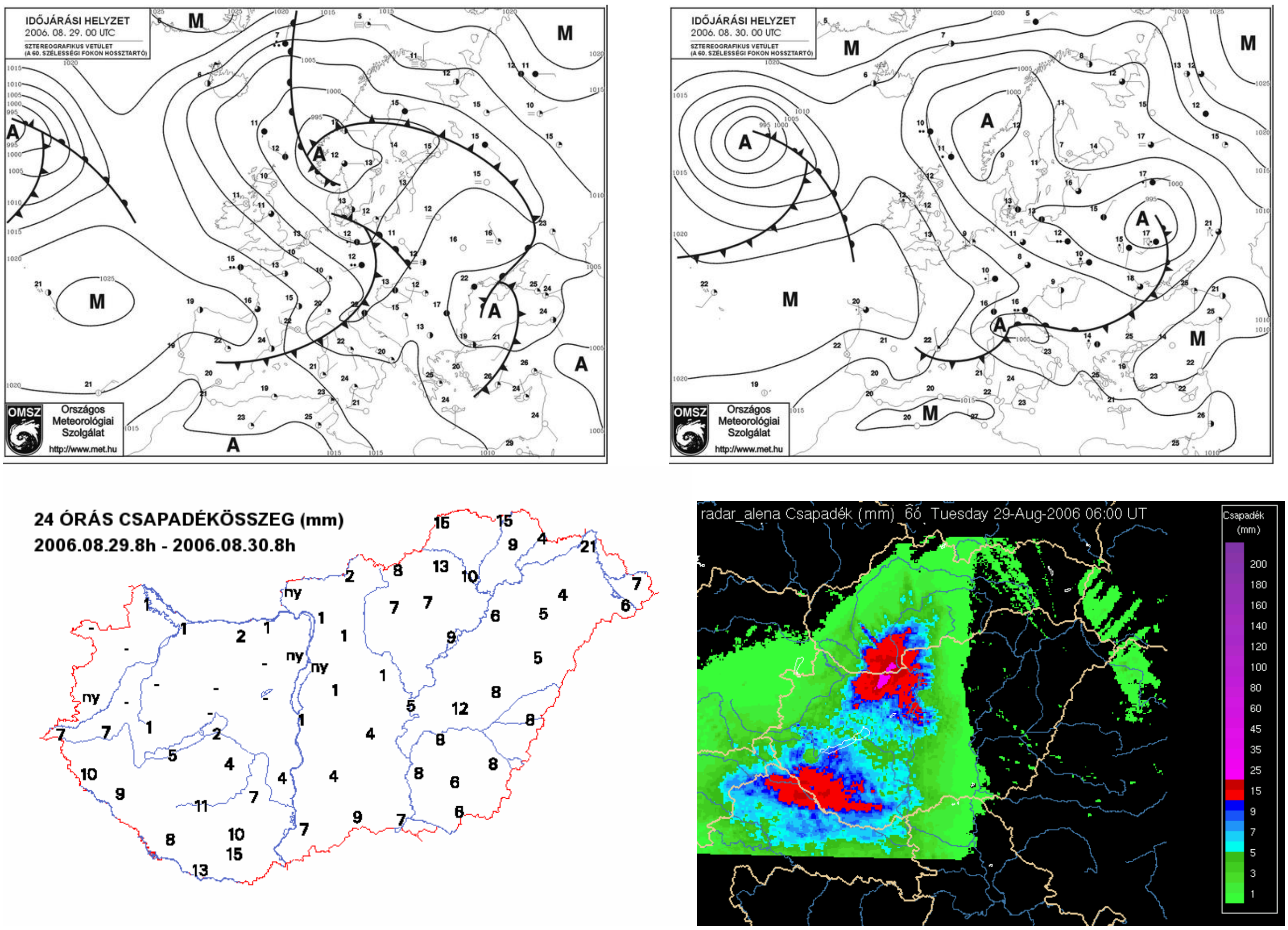


Fig. 1: Weather analysis at 00 UTC of August 29th 2006 (top-left) and next day (top-right). Daily precipitation sum in Hungary for August 29 (bottom-right) and 6h accumulated radar estimate valid at 06UTC (bottom-left).

2.1 Setup of experiments

All experiments were performed with 3D-VAR ALADIN/HU described in details by Bölöni (2005). Here follows its main characteristic only:

- cycle 30t1
- linear grid, 8km horizontal resolution and 49 vertical levels
- domain covers roughly the same area as the formal LACE domain
- 6h assimilation cycle (00, 06, 12, 18 UTC)
- surface (soil) analysis is taken from ARPEGE - long cut-off analysis
- upper air fields are provided by the 3DVAR analysis
- B matrix is computed with ensemble method

and used observations:

- SYNOP surface reports (geopotential)
- TEMP upper air reports (temperature, wind, geopotential, specific humidity)
- ATOVS satellite observations (AMSU-A and AMSU-B radiance)
- AMDAR aircraft reports (temperature, wind)

On the top of above mentioned observations we used also Atmospheric Motion Vector (AMV) following Randriamampianina (2006), let call this experimental setting as reference.

Performed experiments differs in adding SEVIRI data to the reference, let denote this experiment as CE00 or SEVIRI. The way of SEVIRI data use was based on Montmerle (2005), thus near IR 3.9 μm, the ozone 9.7 μm and 13.4 μm channels were blacklisted, one pixel of 5 was extracted from SEVIRI dataset, thinning box of 70 km was used during screening and air-mass bias correction as described in Trojáková and Májek (2006) was applied. Further experiment dedicated to investigation of SYNOP observation, T2m and RH2m were added to analysis only, is denoted as SYNOP or CY00. And last experiment labelled CB00 includes both SYNOP and SEVIRI data in analysis together.

We have used almost 5 days warm-up period (all experiments starts from the same guess on 20060824 06 UTC) and for chosen case 20060829 a 48 hours forecast from 00 analysis was provided. Here follows summary of performed experiments:

- **CR00** - Case Reference
- **CE00** - Case sEviri (CR00 + SEVIRI (with default σ_o))
- **CY00** - Case sYnop (CR00 + SYNOP (analysis of T2m, RH2m added only))
- **CB00** - Case both (CR00 + SEVIRI + SYNOP (analysis of T2m, RH2m added only))

2.2 Impact on analysis

In order to evaluate an impact on analysis we checked diagnostics from observation monitoring, performed verification against observation of our analyzes and special study of increments.

2.2.1 Monitoring

Exhaustive description of monitoring output is out of scope of this report, mostly we have used monitoring to check behavior of SYNOP and SEVIRI observations during the warm-up period (2006082406-2006082900). Fig. 2 shows time evolution of mean and standard deviation of obs-guess and obs-analysis increments for SYNOP and SEVIRI observation. Obs-analysis are smaller in both cases, which approve that information is used in the analysis. There is also number on observation plotted. On average there were used around 700 T2m or RH2m observations a day and around 350 observation for IR channels and 1100 for WV channels.

SEVIRI data were also checked on undesirable bias. Only small bias < 0.2 K was observed and assumed as acceptable, see Fig. 3.

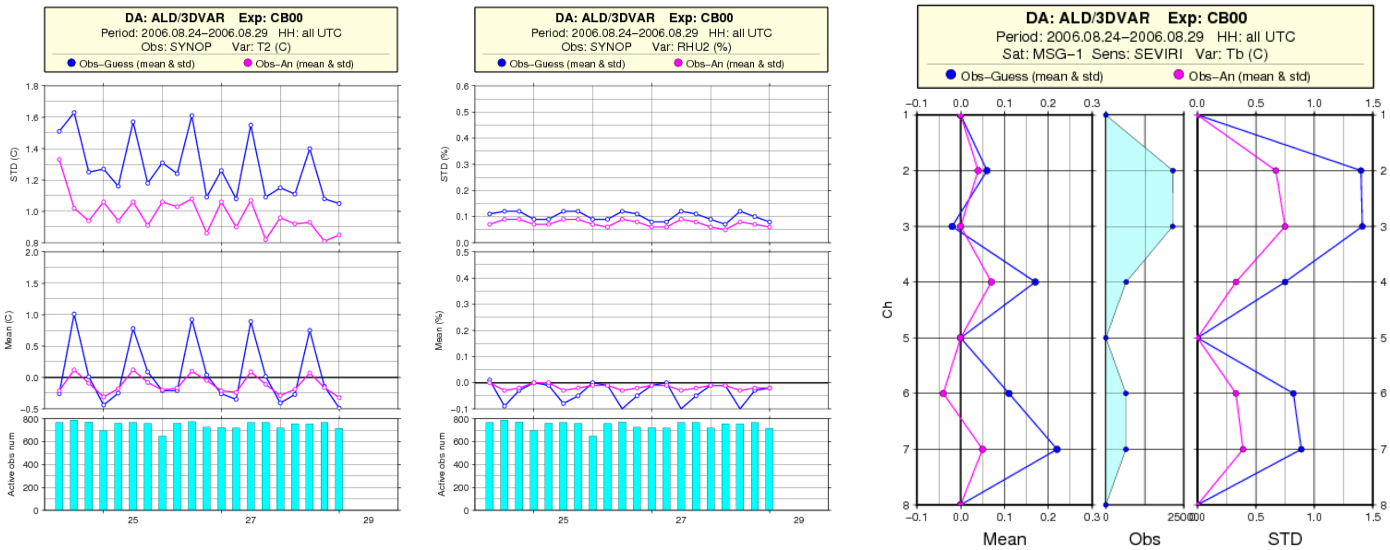


Fig. 2: Monitoring statistics for analysis of SYNOP T2m (left), RH2m (middle) and SEVIRI channels (right). In each graph mean (left) and standard deviation (right) are presented.

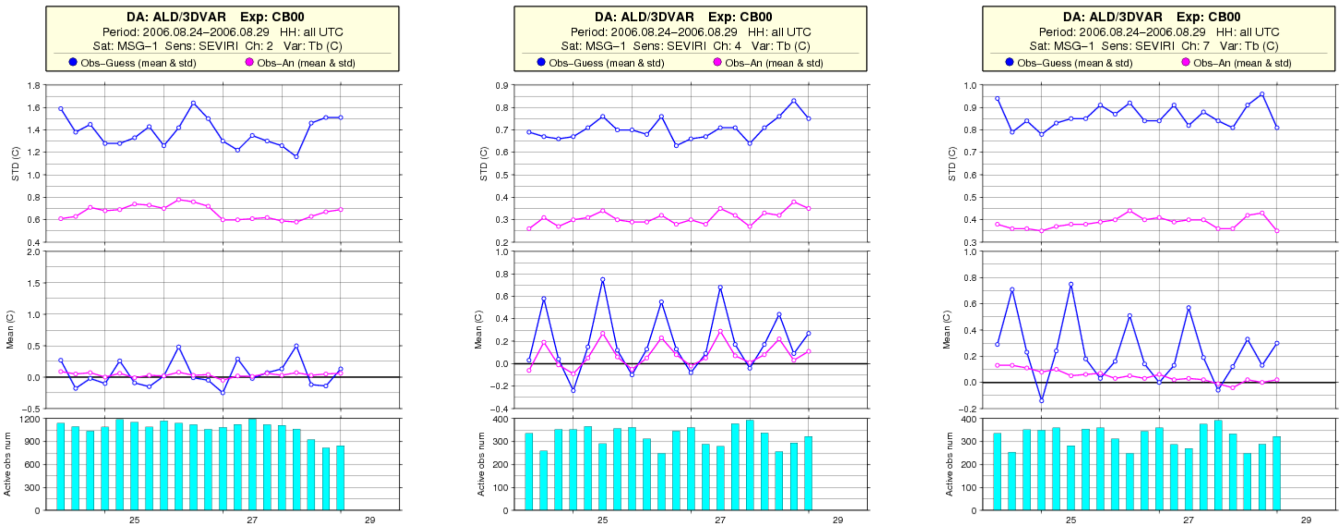


Fig. 3: Monitoring statistics SEVIRI channels #2 (right), #4 (middle) and #7 (right). In each graph mean (bottom) and standard deviation (top) are presented.

2.2.2 Verification against observation

On following figures Fig. 4 - Fig. 6 scores against observations for analyzes of warm-up period are plotted. Although the verification period is too short to make general conclusion, there is apparent positive impact of adding SYNOP observation near the surface and also less pronounced on 1000 hPa, upwards the impact of adding any observation has no clear signal. Concerning BIAS the most noticeable features are near the surface where the use of SYNOPs bring drying in 2m and also less varying temperature BIAS. Unfortunately the impact is almost lost after 6h forecast, as can be seen from the scores of guesses from the same period on Fig. 7 and Fig. 8.

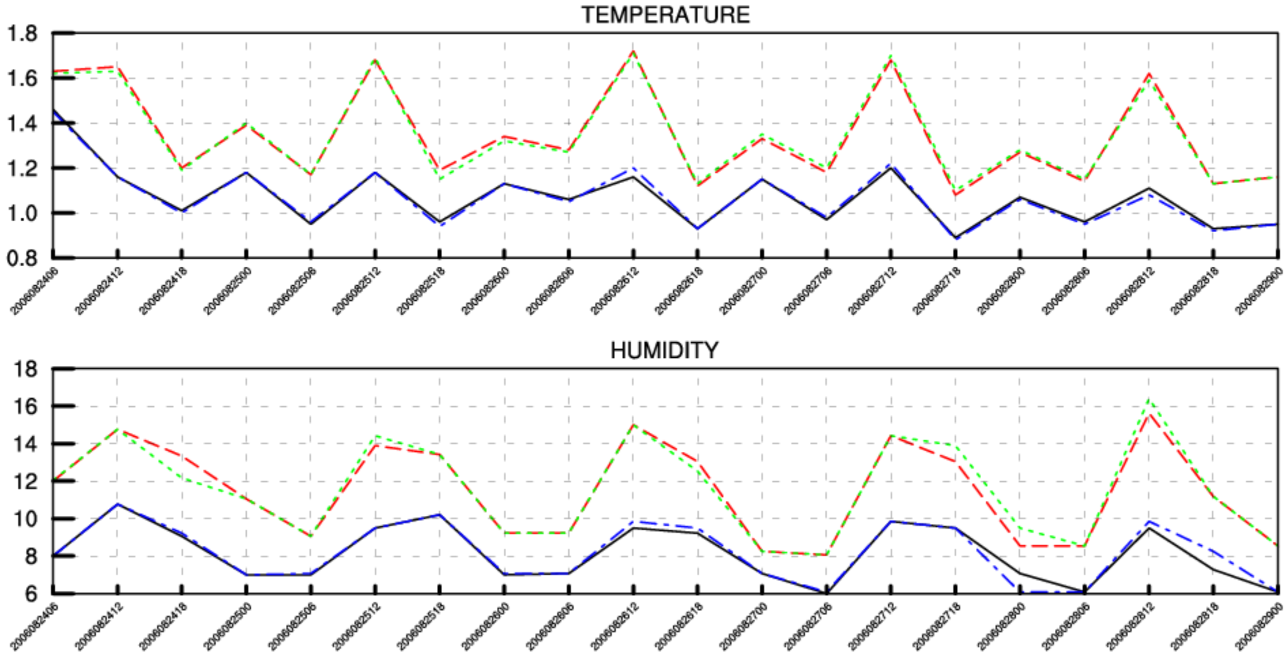


Fig. 4: RMSE scores against observations for analyzes from 20060824 06 UTC till 2006082900 UTC on surface. Reference experiment in green, SEVIRI one in red, SYNOP in blue and **both** SYNOP and SEVIRI in black color.

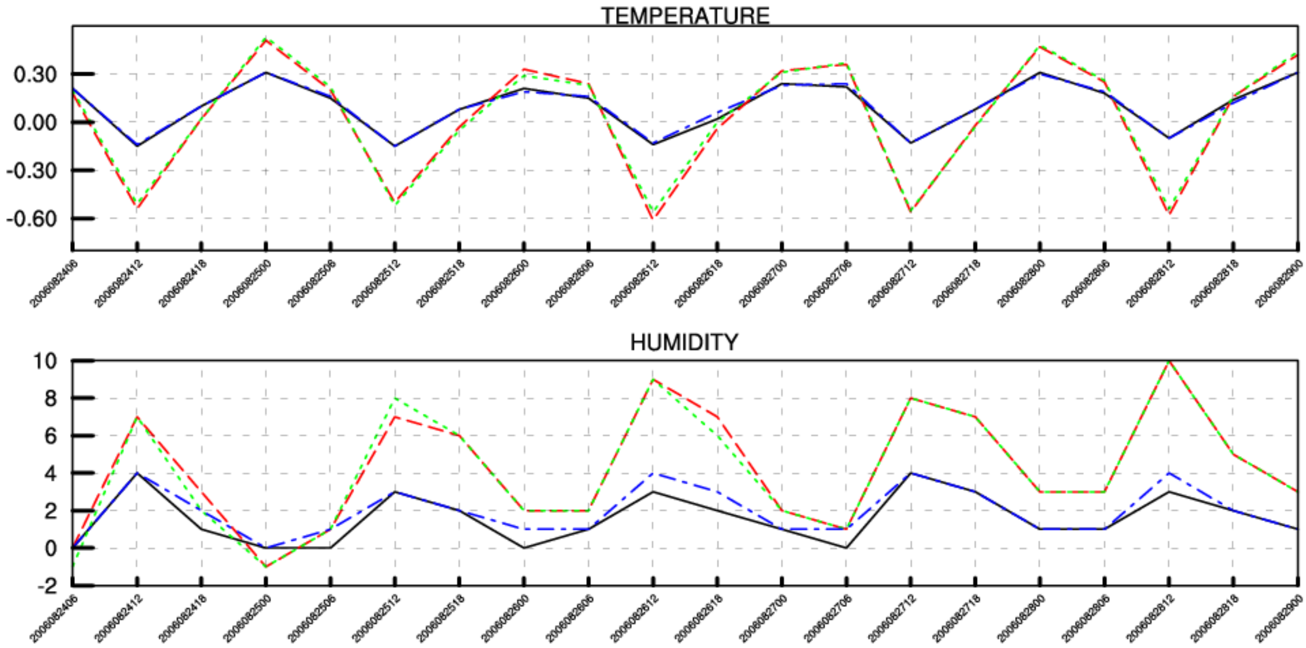


Fig. 5: the same as previous Fig. 4, but BIAS score.

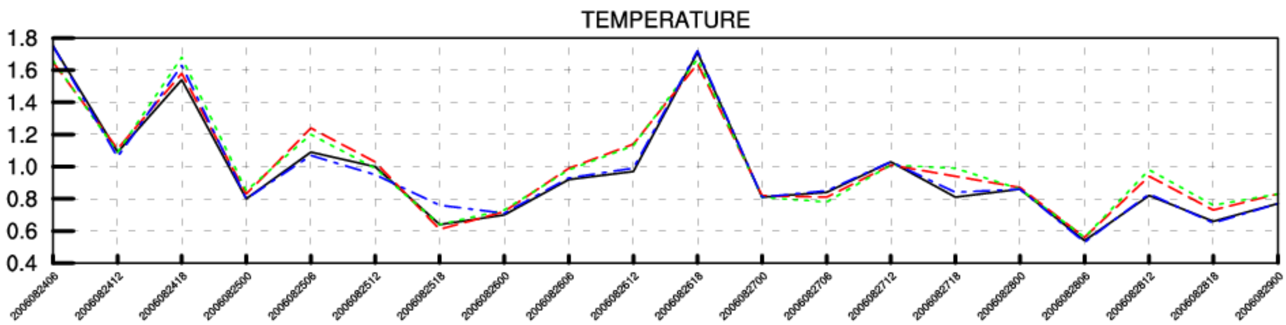


Fig. 6: the same as Fig. 4., but at 1000 hPa.

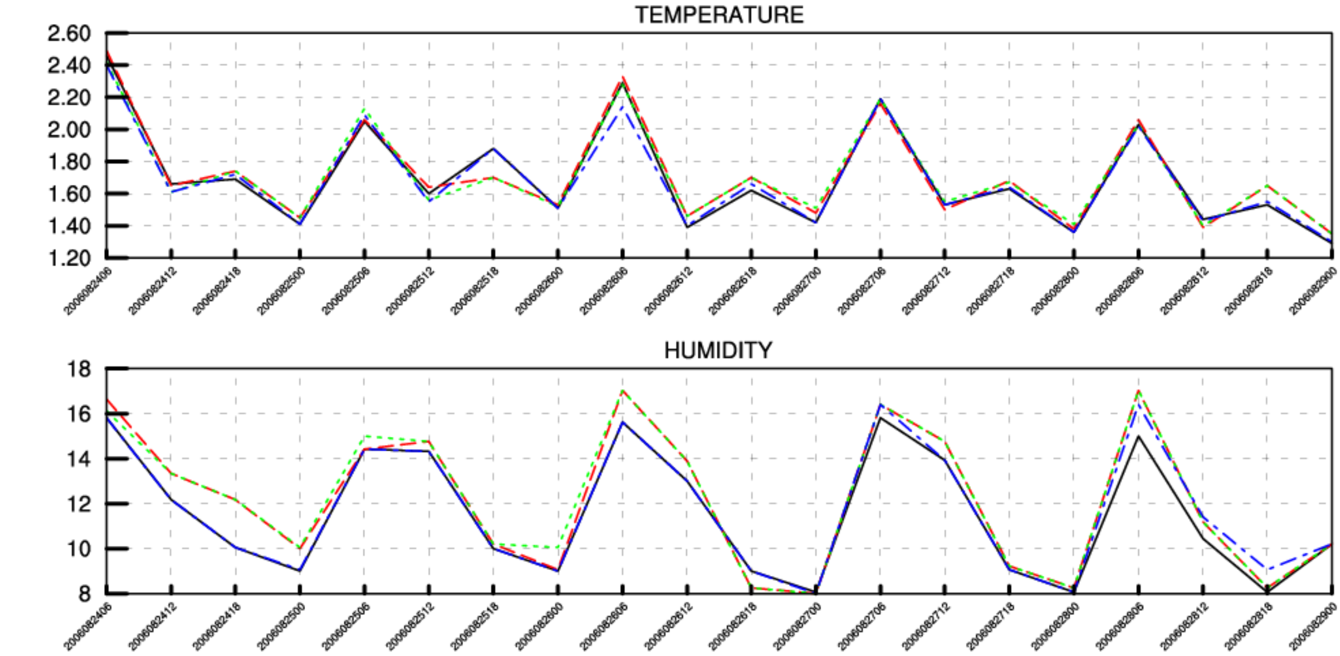


Fig. 7: RMSE scores against observations for guesses from 20060824 06 UTC till 2006082900 UTC on surface. Reference experiment in green, SEVIRI one in red, SYNOP in blue and **both** SYNOP and SEVIRI in black color.

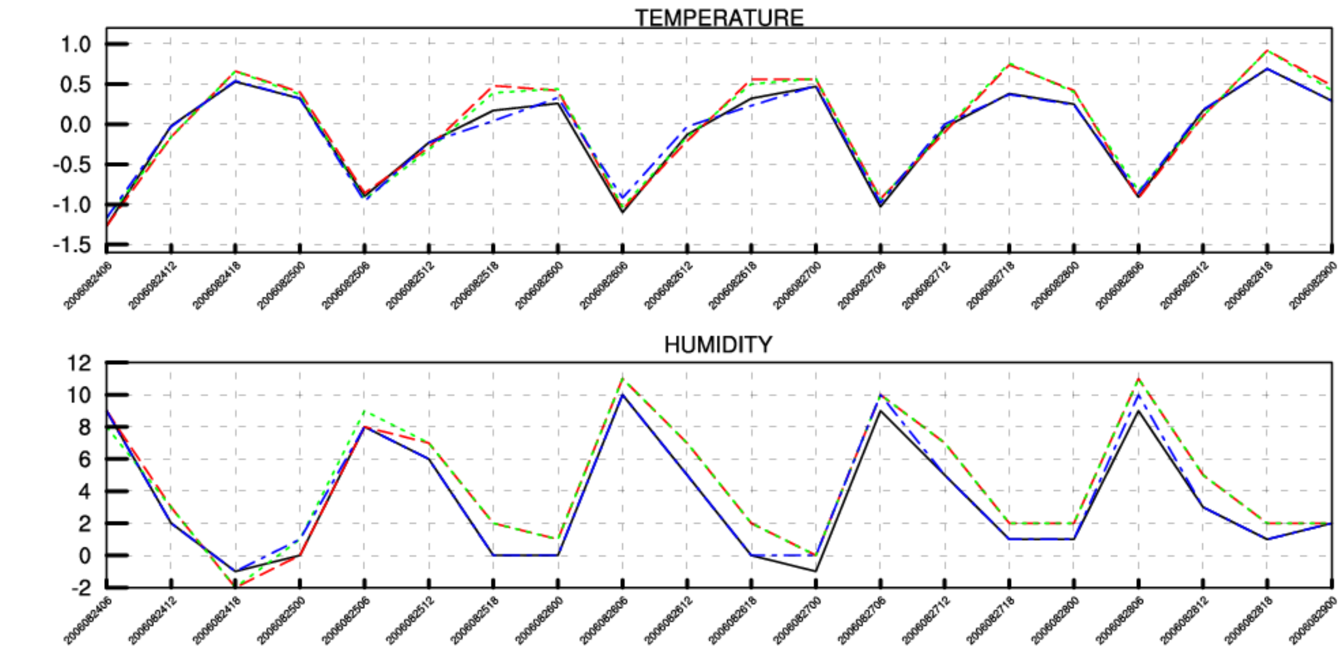


Fig. 8: the same as Fig. 7, but BIAS.

2.2.3 Increments

In order to see how SYNOP and SEVIRI observation acts on their own and together, we performed one assimilation cycle for one run 20060828 00 UTC starting from the same guess, the remaining ATOVS, AIREP, AMV observations were excluded from analysis and only studied observations were used in following special set of experiments:

- CI01 - SYNOP (T2m, RH2m) observation used only
- CI02 - SEVIRI observation used only
- CI03 - SEVIRI and SYNOP observation used only

There are very small differences for T2m and RH2m analysis increments, e.g. between experiment CI01 and CI03 there is difference of 0.01K in mean of T2m analysis increments and 0.01 % for RH2m analysis increments, so on following figures horizontal distribution of an analysis increments of only CI01 experiment are shown.

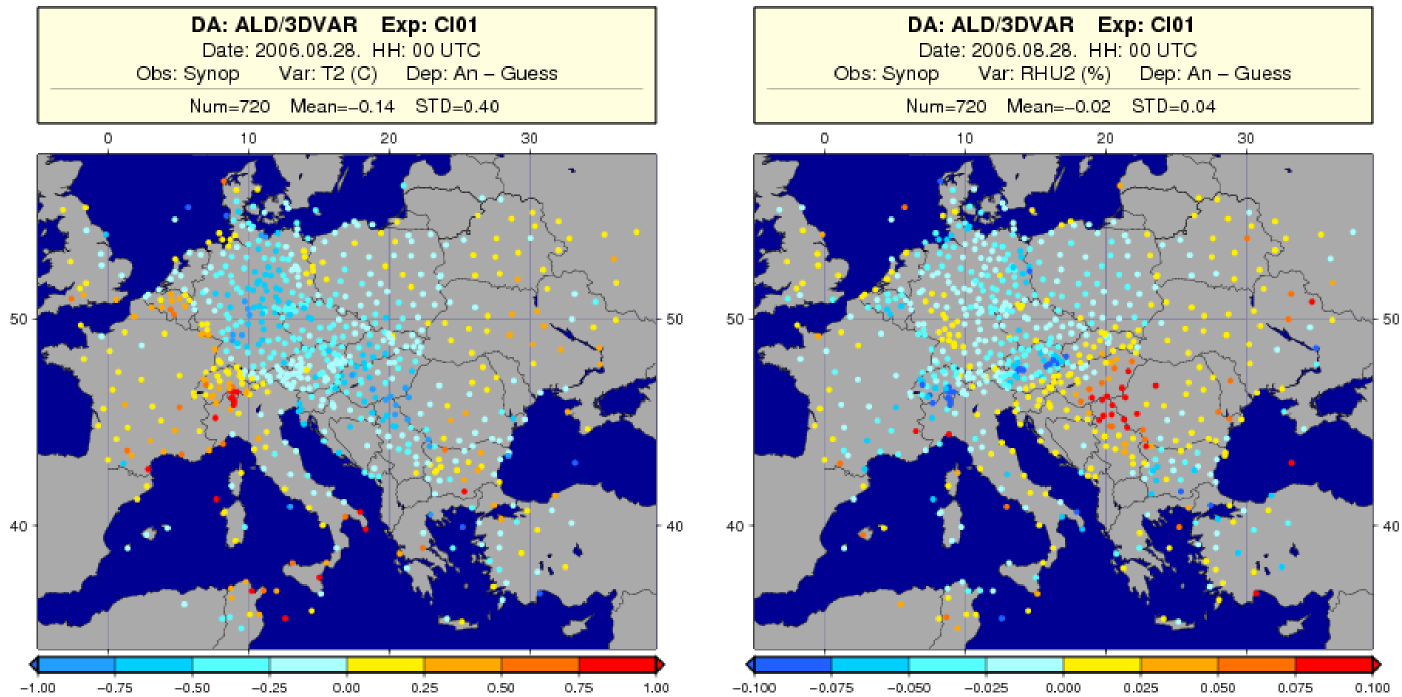


Fig. 9: Horizontal distribution of increments for analyzes from 20060828 00 UTC with only SYNOP observation used for T2m (left) and RH2m (right).

Vertical propagation of these low level increments and mutual interaction of SYNOP and SEVIRI observation was of main interest in this study. On the next figures vertical cross-sections of relative humidity and temperature increments going roughly from Brussels to Sofia for all three experiments are shown.

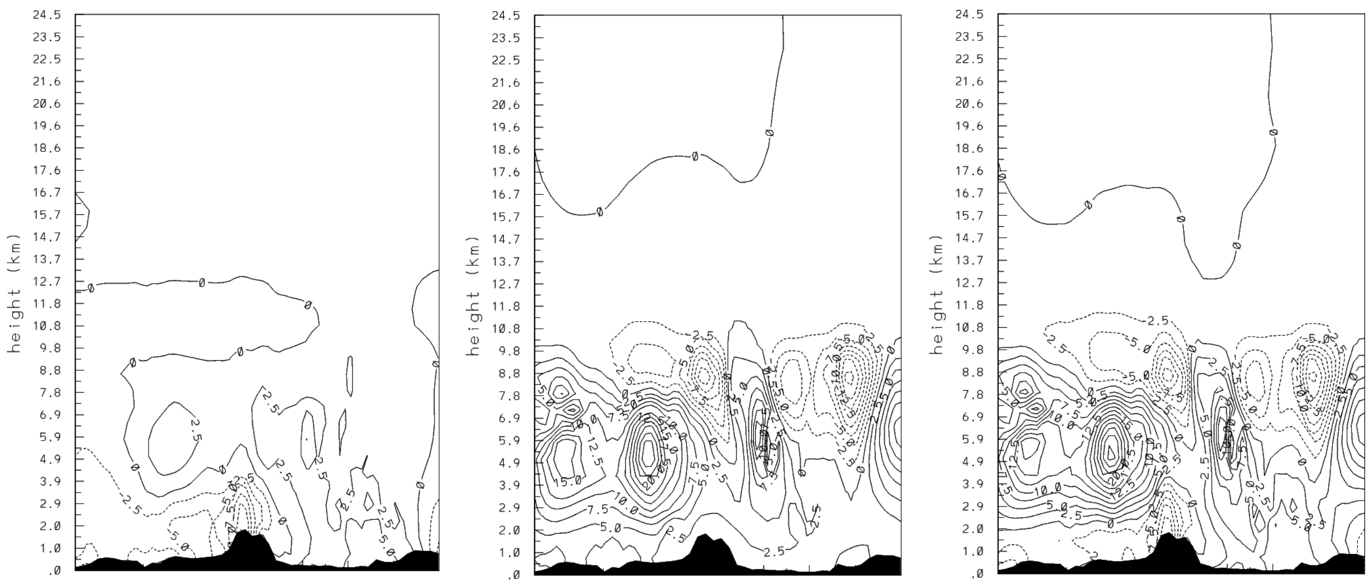


Fig. 10: Vertical cross-section of analysis increments of relative humidity (isolines every 0.1K) with only SYNOP observation used (left), with SEVIRI only (middle) and both SYNOP and SEVIRI together (right).

On Fig. 10 there is apparent impact of T2m and RH2m analysis on relative humidity mostly near the surface, but extends up to 10km height. SEVIRI data acts over all troposphere. When both observation are used, there is noticeable reduction of drying caused by SYNOP observation in front of and over Alps, but behind the increments are of the same sign, so there is even more moistening. Similar behavior can be found on the next figure Fig. 11. for temperature increments. There the use of both observation types causes mostly cooling near the surface and warming upwards and results in combination of impacts.

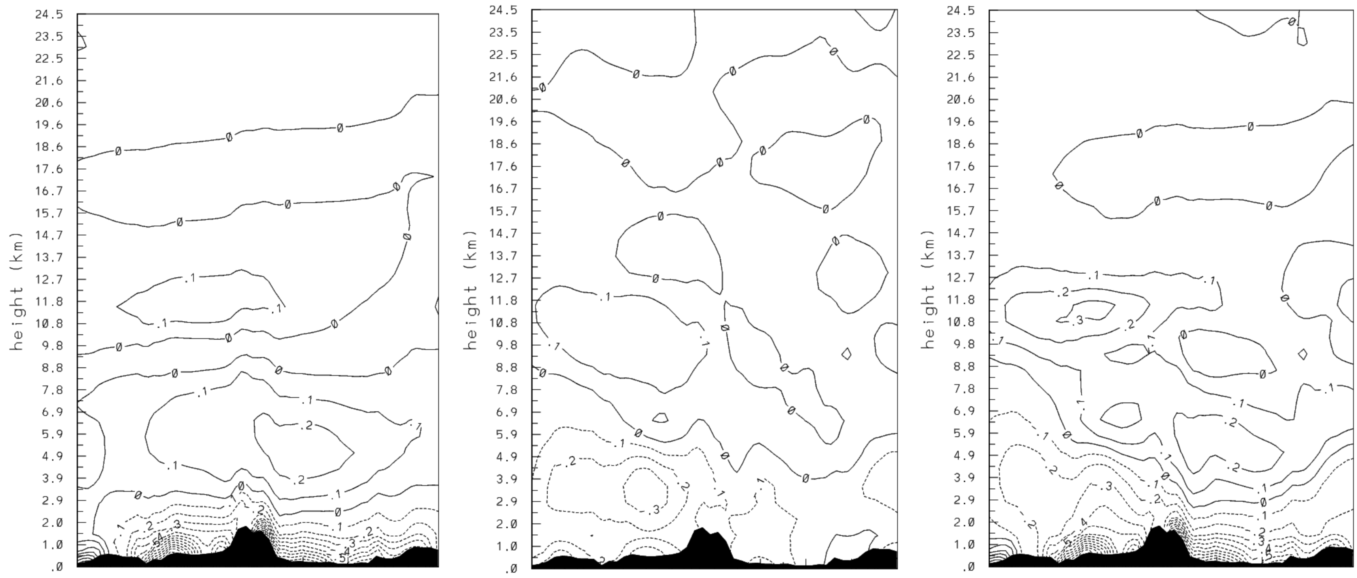


Fig. 11: Vertical cross-section of analysis increments of temperature (isolines every 0.1K) with only SYNOP observation used (left), with SEVIRI only (middle) and both SYNOP and SEVIRI (right).

It was difficult to drive conclusions from this increments study as an interaction of SYNOP and SEVIRI increments differs locally very much and study is valid for a single run only.

2.3 Impact on forecast

In order to evaluate an impact of SYNOP and SEVIRI interaction on model forecast we performed comparison against observations (VERAL/OVISYS) and subjective verification with radar over Hungary.

2.3.1 Verification against observation

Forecasts for this case differ very little in terms of RMSE or BIAS scores. There is very small improvement on surface for T2m and RH2m when assimilation SYNOP observation (experiments CY00 and CB00) and for MSLP all experiments outperform reference for second day, see Fig 12.

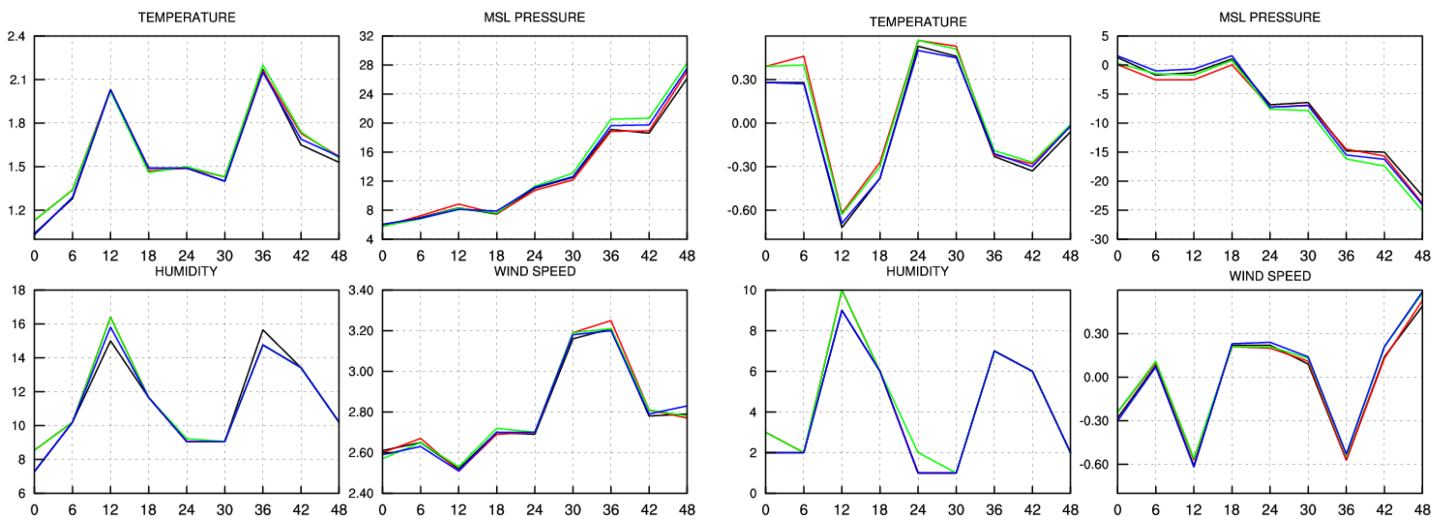


Fig. 12: RMSE (left) and BIAS (right) for production from 20060829 00UTC on surface. Reference experiment CR00, SYNOP one CY00, SEVIRI one CE00 and both SYNOP and SEVIRI together in black color.

General issue of this case study was to get hint if SYNOP observation can help to the better performance of SEVIRI and also an evaluation of impact of SYNOP observation themselves. On following Fig. 13-15 the upper-air scores for SYNOP experiment CY00 and the combination of both SYNOP and SEVIRI (CB00) are displayed.

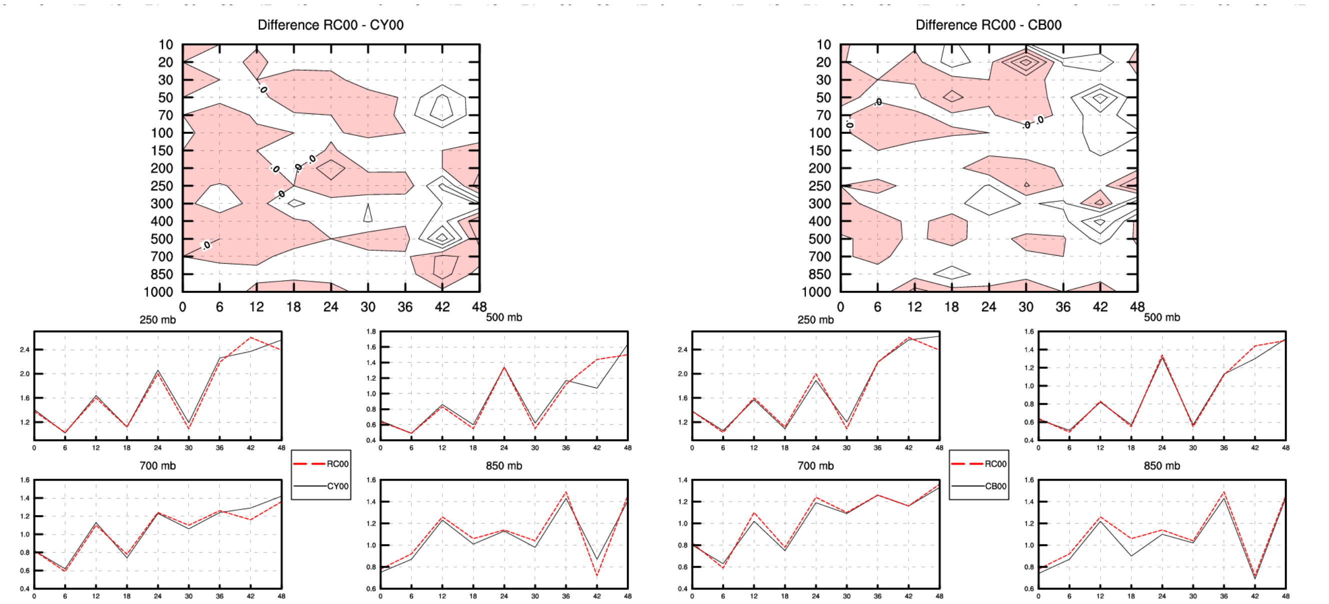


Fig. 13: RMSE of T red areas denote negative impact of used observation - SYNOP (left) and both (right)

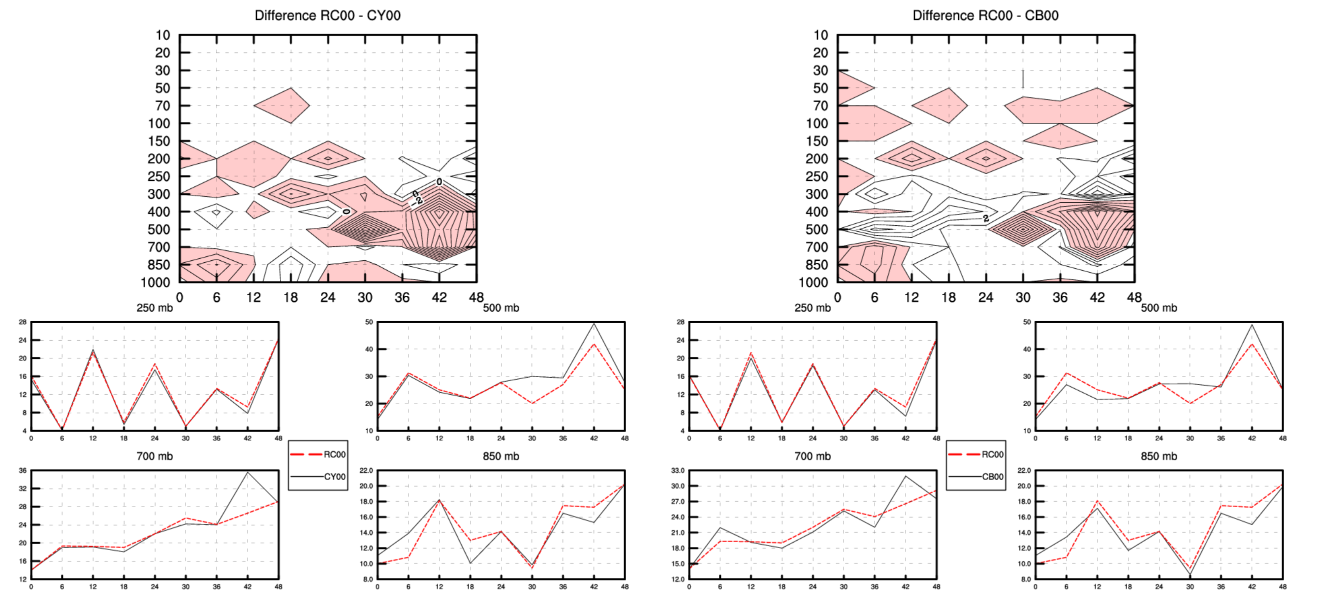


Fig. 14: RMSE of RH red areas denote negative impact of used observation - SYNOP (left) and both (right)

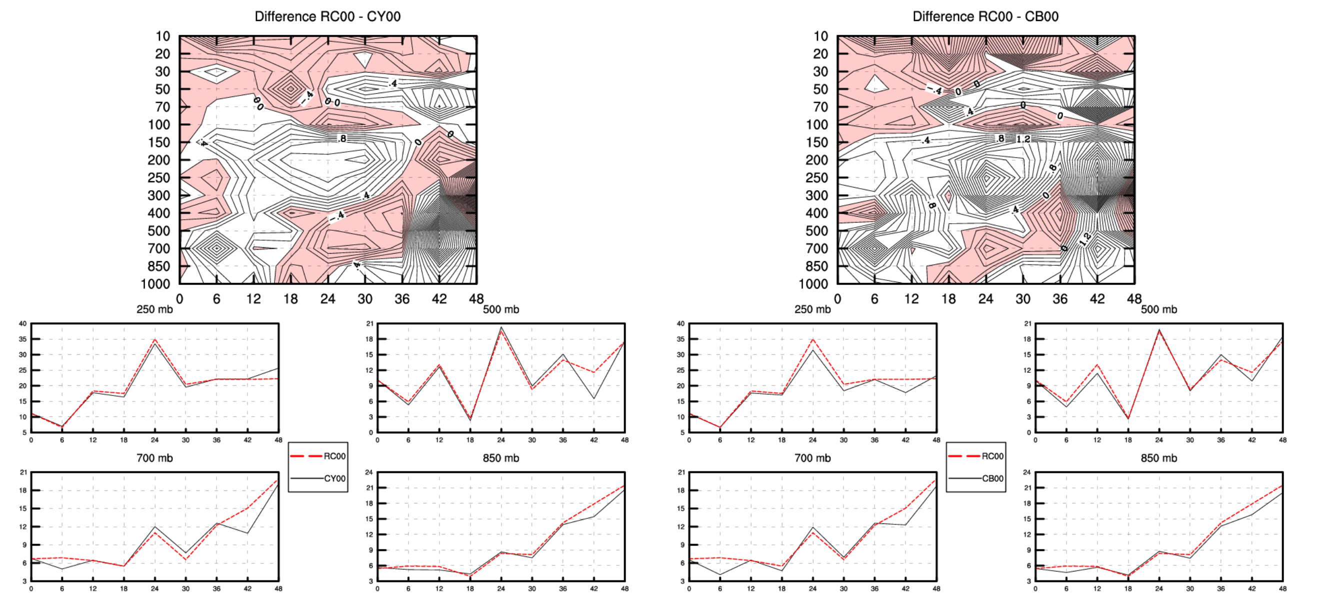


Fig. 15: RMSE of ϕ red areas denote negative impact of used observation - SYNOP (left) and both (right)

For all parameters the use of both SYNOP and SEVIRI performs slightly better, than SEVIRI or SYNOP used alone, SYNOP alone degraded mostly temperature above 700hPa for the first 12H of forecast. Relative humidity is degraded with respect to the reference for all experiments (CE,CY,CB) for the first 12H up to 700hPa (order of a few %) and forecast for the second day between 700 and 300 hPa by 10%. Geopotential is mostly improved but the extent is very small of order several m^2s^{-2}.

2.3.2 Subjective verification with radar over local domain of interest/Hungary

Precipitation were compared with radar estimates for 6h and 1h accumulated amounts as is illustrated by Fig. 16 for the first 6h forecast, there are quantitative differences in experiments, but they don't make any qualitative improvement, at least over Hungary.

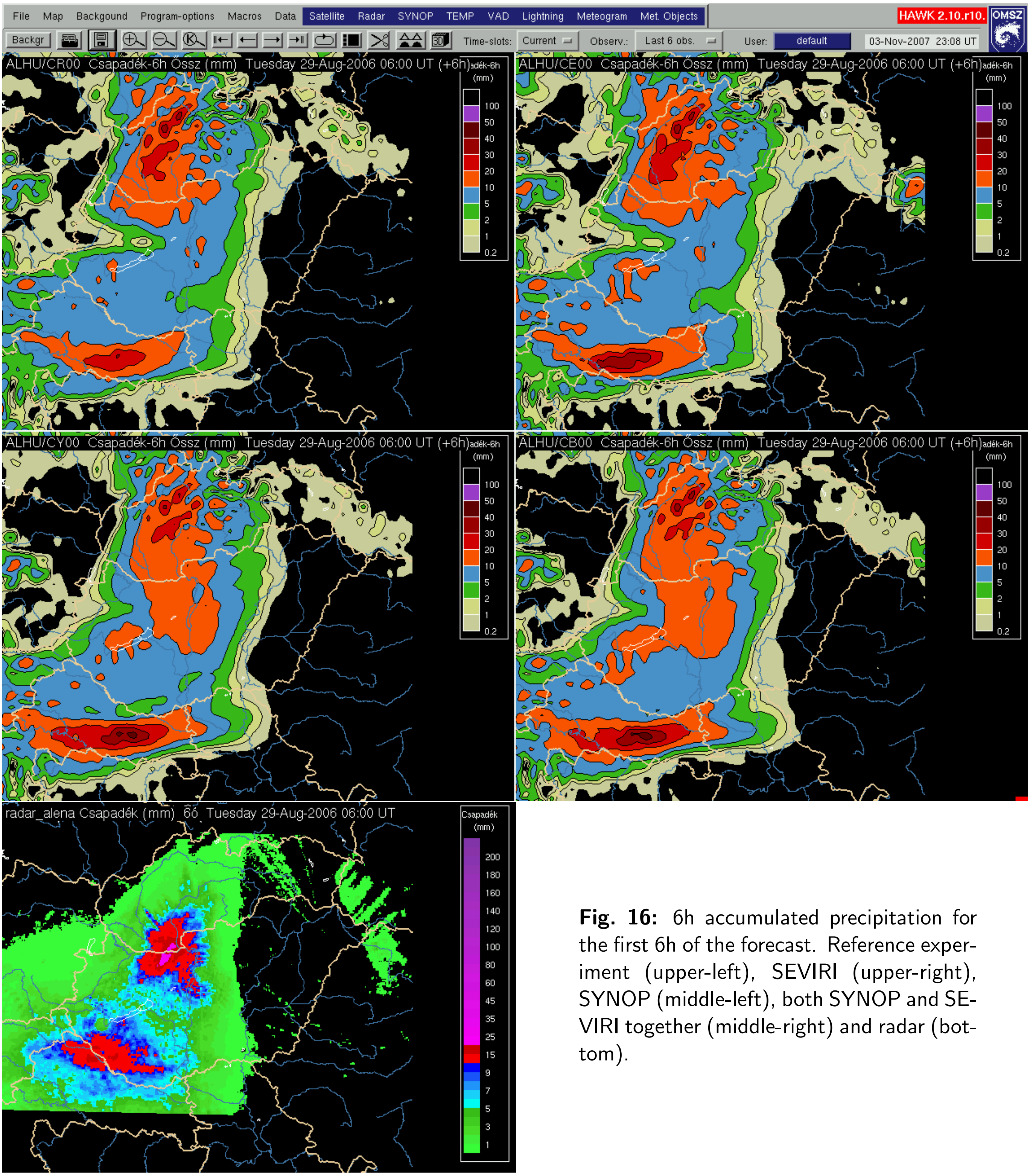


Fig. 16: 6h accumulated precipitation for the first 6h of the forecast. Reference experiment (upper-left), SEVIRI (upper-right), SYNOP (middle-left), both SYNOP and SEVIRI together (middle-right) and radar (bottom).

2.3.3 Objective verification scores for precipitation

Precipitation were evaluated with local verification software OVISYS, which uses and interpolation to observation point, but not model obs-operator. RMSE and BIAS scores for all experiments are on Fig. 17, there can be seen positive impact mainly for both experiments containing SYNOP observations (CY00 and CB00), but also CE00 with only SEVIRI data performs quite well except last forecast range. Similar results were obtained for 12h precipitation too (not shown).

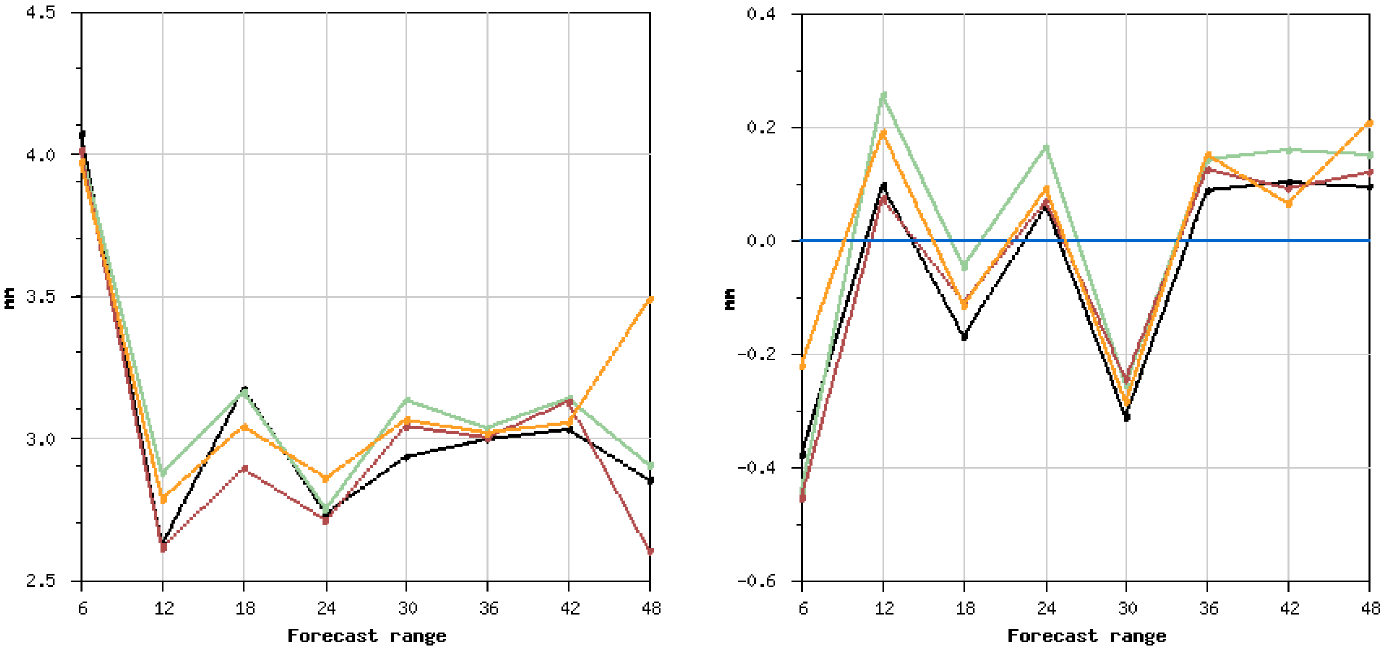


Fig. 17: RMSE (left) and BIAS (right) for 6h precipitation for production from 20060829 00 UTC, Reference run CR00, SYNOP run CY00, SEVIRI run CE00 and both SYNOP and SEVIRI included run CB00 in black color.

Contingency tables can be used for an evaluation of precipitation, on Fig. 18 an example of tables for 6h accumulated precipitation of the first 6H forecast is shown, where for no-rain class experiments including SYNOPs perform better and for category of precipitation $> 10mm$ all studies perform better then reference CR00. Direct use of contingency table for 4 experiments each of 48H forecast comprises intercomparison of 32 tables, which is not very convenient. Thus several scores derived from contingency tables were evaluated. Here follow scores definitions taken from Stanski et al (1989):

- **Percent Correct (PC)** is defined as the sum of the diagonal elements divided by the total number of events. Overall score can be greatly influenced by the most frequent categories and can thus give misleading information. This can be somehow eliminated by calculating PC by category.
- **False Alarm Ratio (FAR)** is defined as the sum of "wrong" forecast divided by the number of forecast for each category. FAR is sensitive ONLY to false predictions, not to missed events.
- **Probability of Detection (POD)** is defined as the number of correct divided by the number of observed in each category. It is a measure of the ability to correctly forecast a certain category. Like FAR it is not a complete score and is sensitive ONLY to missed events, not false alarms.
- **Bias or Frequency Bias (B)** is defined as the number forecast divided by the number observed for each category. It measures the ability to forecast events at the same frequency as found in the sample without regard to forecast accuracy.
- **Heidke Skill Score (HSS)** is defined as decimal fraction the percentage of forecasts which are correct after eliminating those forecasts which would have been correct on the basis of chance (or some other standard such as persistence, climatology or some other forecast, but we have used chance in our consideration).

CR00

előrejelzés	<=0.1	<=2	<=10	>10	Osszesen
<=0.1	177	17	5	0	199
<=2	113	78	49	1	241
<=10	13	35	55	19	122
>10	1	1	6	7	15
Osszesen	304	131	115	27	577

megfigyelés

	<=0.1	<=2	<=10	>10
B=	0.655	1.840	1.061	0.556
PC=	0.742	0.626	0.780	0.951
POD=	0.582	0.595	0.478	0.259
FAR=	0.111	0.676	0.549	0.533
F=	0.081	0.365	0.155	0.015
KSS=	0.502	0.230	0.324	0.245
TSS=	0.543	0.265	0.302	0.200
ETS=	0.326	0.097	0.195	0.184
HSS=	0.492	0.177	0.316	0.310
OR=	23.946	2.555	5.007	23.712
ORSS=	0.920	0.437	0.667	0.919

CY00

előrejelzés	<=0.1	<=2	<=10	>10	Osszesen
<=0.1	210	27	10	0	247
<=2	86	70	42	3	201
<=10	7	33	55	13	108
>10	1	1	8	11	21
Osszesen	304	131	115	27	577

megfigyelés

	<=0.1	<=2	<=10	>10
B=	0.812	1.534	0.939	0.778
PC=	0.773	0.667	0.804	0.955
POD=	0.691	0.534	0.478	0.407
FAR=	0.150	0.652	0.491	0.476
F=	0.136	0.294	0.122	0.018
KSS=	0.555	0.241	0.356	0.389
TSS=	0.616	0.267	0.327	0.297
ETS=	0.379	0.113	0.229	0.278
HSS=	0.549	0.202	0.364	0.435
OR=	19.925	2.759	6.590	37.125
ORSS=	0.904	0.468	0.736	0.948

CE00

előrejelzés	<=0.1	<=2	<=10	>10	Osszesen
<=0.1	178	15	5	0	198
<=2	113	74	51	1	239
<=10	12	41	47	14	114
>10	1	1	12	12	26
Osszesen	304	131	115	27	577

megfigyelés

	<=0.1	<=2	<=10	>10
B=	0.651	1.824	0.991	0.963
PC=	0.747	0.615	0.766	0.950
POD=	0.586	0.565	0.409	0.444
FAR=	0.101	0.690	0.588	0.538
F=	0.073	0.370	0.153	0.025
KSS=	0.512	0.195	0.256	0.419
TSS=	0.549	0.250	0.258	0.293
ETS=	0.335	0.082	0.152	0.271
HSS=	0.502	0.151	0.257	0.427
OR=	26.771	2.211	3.838	30.629
ORSS=	0.928	0.377	0.587	0.937

CB00

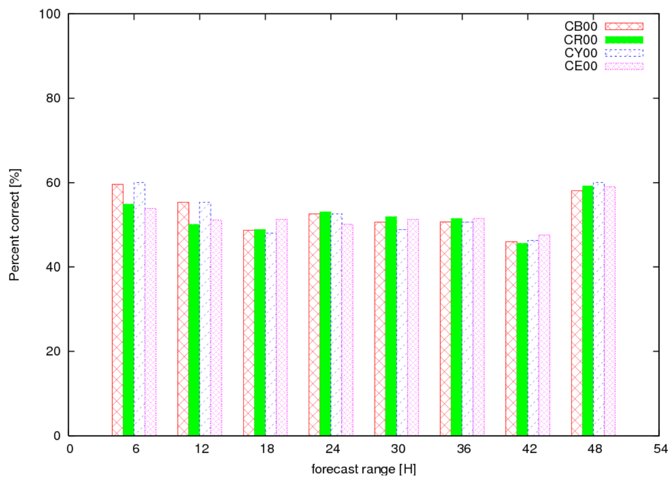
előrejelzés	<=0.1	<=2	<=10	>10	Osszesen
<=0.1	202	22	8	0	232
<=2	91	77	42	4	214
<=10	11	31	54	12	108
>10	0	1	11	11	23
Osszesen	304	131	115	27	577

megfigyelés

	<=0.1	<=2	<=10	>10
B=	0.763	1.634	0.939	0.852
PC=	0.771	0.669	0.801	0.951
POD=	0.664	0.588	0.470	0.407
FAR=	0.129	0.640	0.500	0.522
F=	0.110	0.307	0.126	0.022
KSS=	0.555	0.281	0.343	0.386
TSS=	0.605	0.287	0.320	0.282
ETS=	0.377	0.130	0.220	0.262
HSS=	0.547	0.229	0.351	0.415
OR=	22.775	3.216	6.115	30.823
ORSS=	0.916	0.526	0.719	0.937

Fig. 18: Contingency tables and scores for different categories of 6h accumulated precipitation for +6H forecast (observation in columns and forecast in rows).

Only for some of above mentioned scores. e.g. Percent Correct (PC) and Heidke Skill Score (HSS), make sense to compute single score for all categories at given time range, so called overall scores. Time evolution of those overall scores are displayed on following figure Fig. 19. For the first 12H of forecast experiments including SYNOP observations (CY00 and CB00) improved PC and HSS scores and all experiment more or less equal afterwards.



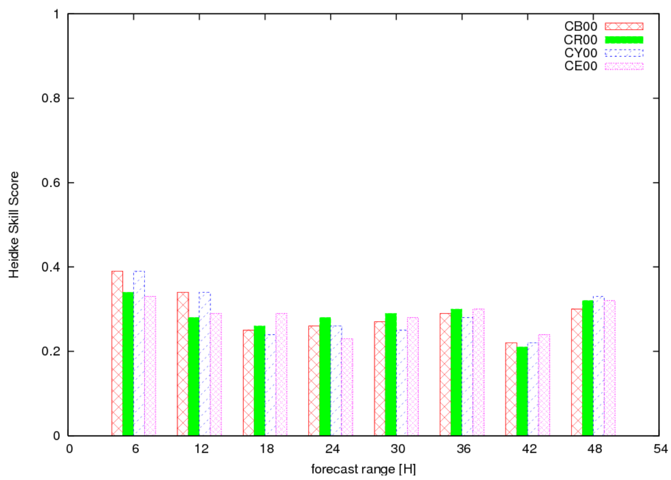


Fig. 19: Overall Percent Correct (left) and Heidke Skill Score (right) for 6h accumulated precipitations, Reference as in green, SYNOP experiment in blue, SEVIRI one in violet and both SYNOP and SEVIRI together in red color.

As pointed by Stanski st al (1989) any of the overall score of the contingency table is that they compress the information contained in the elements of the table into one number, resulting in a loss of information. Thus we checked POD, FAR, B and HSS scores for each category too. For no-rain category (< 0.1mm) there for the first 12H forecast 3% percent increase of PC, improved frequency bias, but still there is underforecasting of precipitation for this category. Also POD improved for CY00 and CB00, but at the cost of FAR increase. HSS confirm positive impact for SYNOP and SYNOP and SEVIRI usage for the first 12 hours, see Fig. 20 and 21.

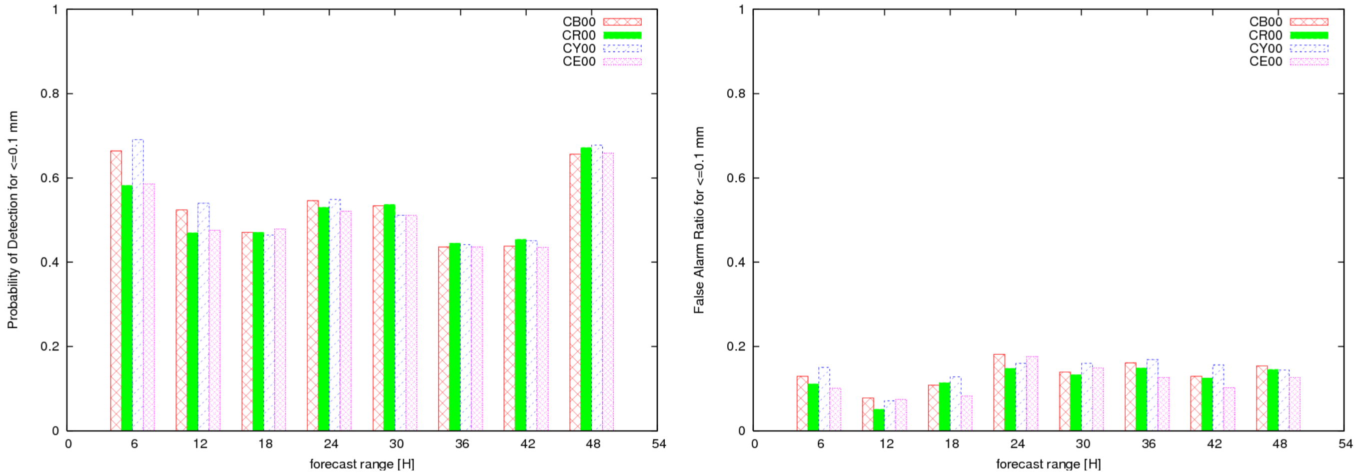


Fig. 20: POD (left) and FAR (right) for 6h accumulated precipitation $<= 0.1mm$, Reference as in green, SYNOP experiment in blue, SEVIRI one in violet and both SYNOP and SEVIRI together in red color.

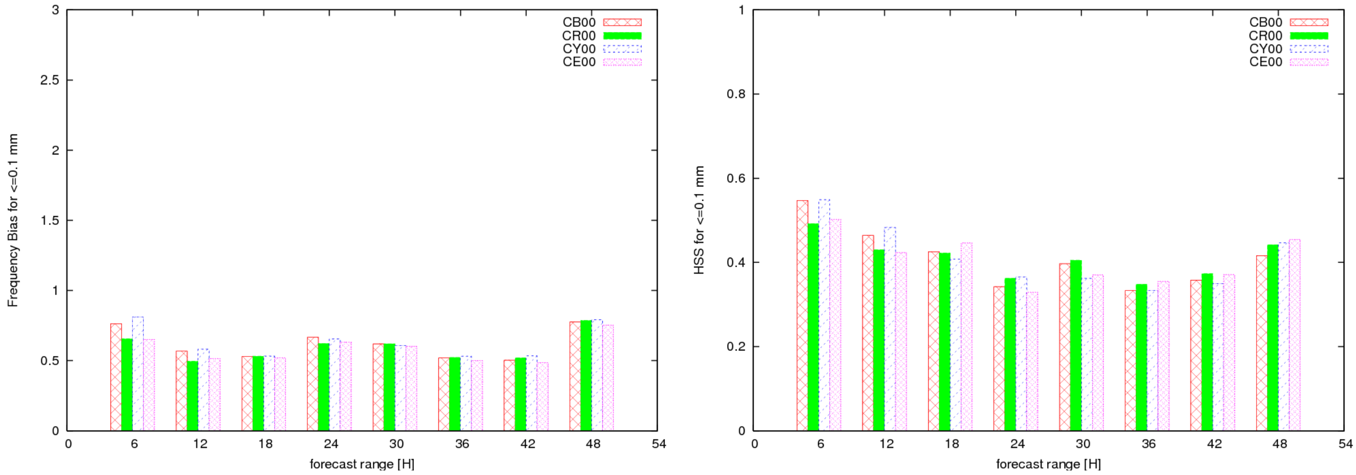


Fig. 21: the same as Fig. 20, but B (left) and HSS (right)

For category of light precipitation < 2 mm there are not big differences in scores for all experiments, for category < 10 mm the improvement of 7-10% of POD and decreased FAR, but for 12H forecast only (see Fig. 22-23). The last category of precipitation more then 10 mm the results does not have any clear signal (see Fig. 24 and Fig. 25), what could be due to small sample which is not representative. Since the creation of contingency table represent a stratification of the data set into categories and mainly we used just one case, e.i. single 48H forecast, this can create sample size problem.

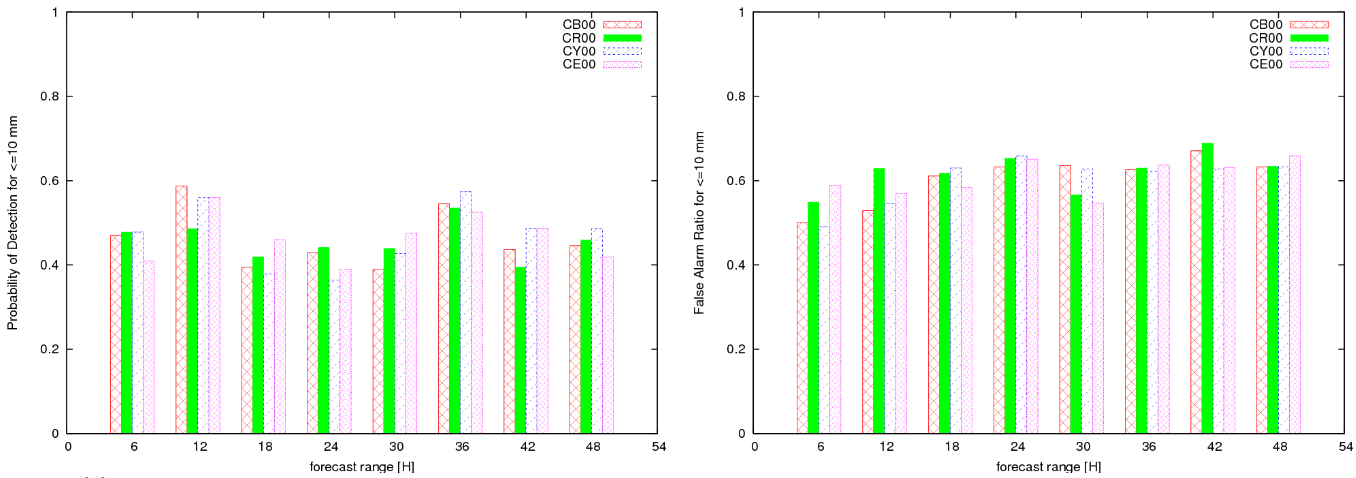


Fig. 22: the same as Fig. 20, but $<= 10mm$.

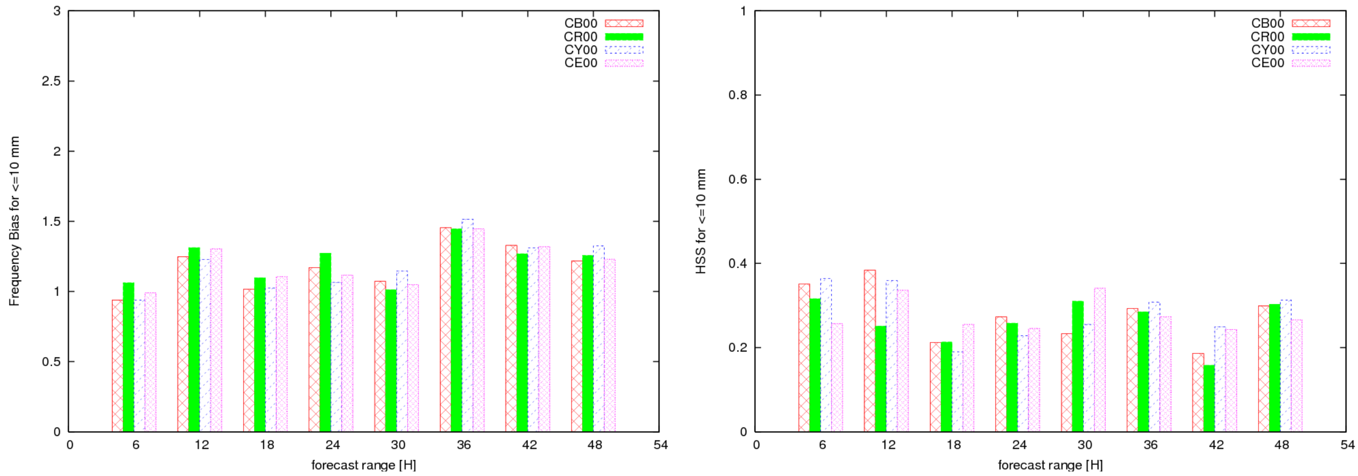


Fig. 23: B (left) and HSS (right) for 6h accumulated precipitation $<= 10mm$, Reference as in green, SYNOP experiment in blue, SEVIRI one in violet and both SYNOP and SEVIRI together in red color.

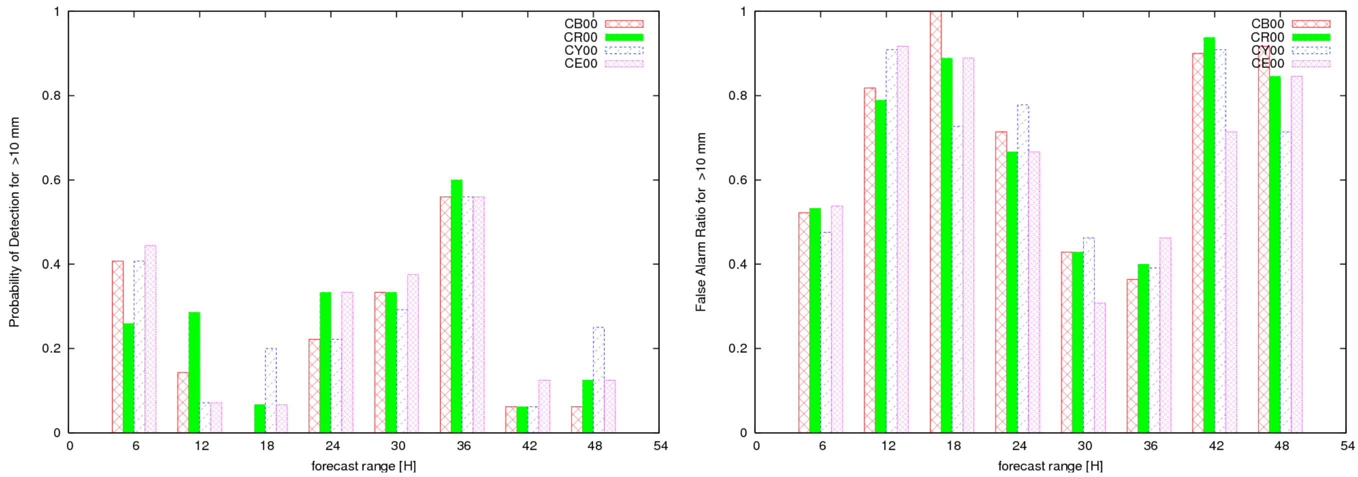


Fig. 24: POD (left) and FAR (right) for 6h accumulated precipitation $> 10mm$, Reference as in green, SYNOP experiment in blue, SEVIRI one in violet and both SYNOP and SEVIRI together in red color.

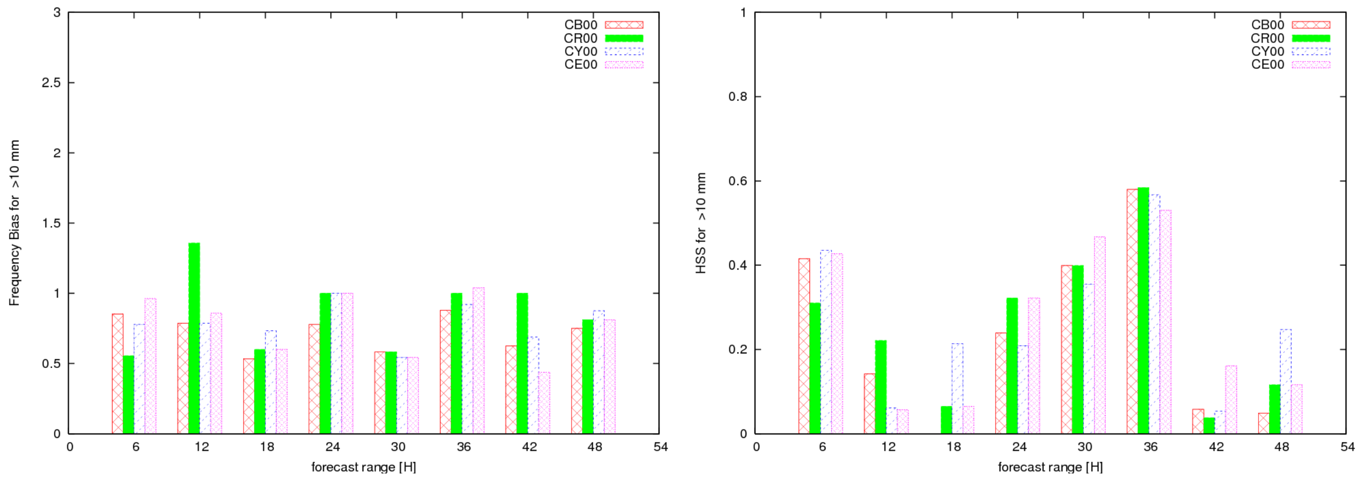


Fig. 25: B (left) and HSS (right) for 6h accumulated precipitation $> 10mm$, Reference as in green, SYNOP experiment in blue, SEVIRI one in violet and both SYNOP and SEVIRI together in red color.

2.4 Summary

Main aim of this case was to study of SYNOP T2m and RH2m analysis behavior alone and evaluation of interaction with SEVIRI data analysis. At first we have checked correct analysis behavior of both studied observations and proper bias correction of SEVIRI data within the monitoring system. Impact on analysis was evaluated against observations (actually used in assimilation itself, which can be assumed as biased, but we have faced technical difficulties with running verification with respect to ECMWF analysis). Objective scores against observation showed positive impact near the surface of assimilating SYNOP observation, but this impact is almost lost after 6h forecast. From increment study was very difficult to drive general conclusion, there was found on some areas desired complementarity of SYNOP and SEVIRI observation (SEVIRI helped to decrease too strong vertical propagation of 2m increments of SYNOP), but there were also cases where the increments have the same sign and this results in combination of both impacts. Further we have focused on evaluation of impact on the forecasts. Objective scores against observation showed that the use of SYNOP and SEVIRI observation together performs slightly better, than SYNOP or SEVIRI data alone (generally all differences are very small). The evaluation of precipitation was of great importance in this study. The subjective comparison with radar over Hungary showed quantitative differences, but no qualitative improvement in any case. The objective scores of 6h-precipitation showed positive impact of assimilation SYNOP or SYNOP and SEVIRI data for the first 12H of forecast at least. Generally the use of SYNOP and SEVIRI observation together showed skills which worth to evaluate for longer period, because we still have to keep in mind this results are valid for one case study only.

3 Longer period impact studies

This section contains at first an amendment to my last report focused on impact of SEVIRI data alone, where the verification of precipitation was missing. Just to recall we studied period from 20060826 till 20060923. The first 2 days were taken for warming up of the assimilation cycle and the remaining 27 days for impact studies. All experiments started from the same guess at 20060826 00 UTC and we provided 48 hours forecast from 00 UTC analysis. Further the results of assimilation both SYNOP and SEVIRI data are presented for the same period.

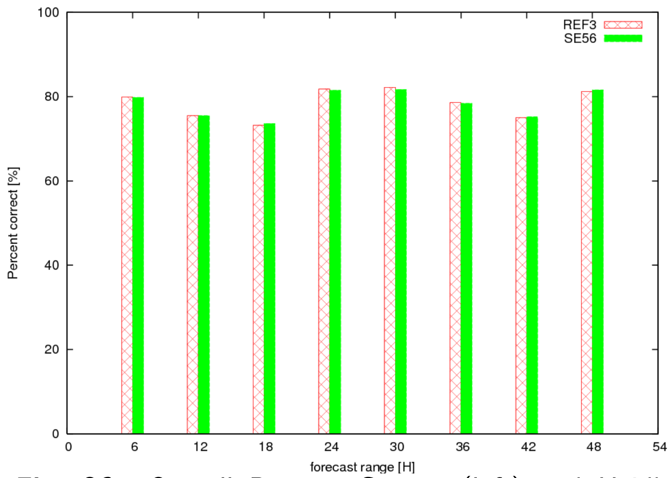
3.1 Impact of SEVIRI data and its tuning on precipitation

The same objective scores described in Section 2.3.3 were used for precipitation evaluation. Previous experiments were dedicated to "refinement" for more efficient use of SEVIRI data in ALADIN/HU 3DVAR system (as the use of ensemble B matrix or tuning of SEVIRI σ_o). For more details see Trojáková (2007) and here only short descriptions and labelling of experiments is presented for each comparison.

Impact on precipitation of SEVIRI data with respect to reference experiment

- **REF3** - SYNOP, TEMP, AMDAR, ATOVS, AMV observations with ensemble B matrix - reference
- **SE56** - REF3 + SEVIRI with default σ_o

there was found very small differences, if any, in overall PC and HSS scores (see Fig. 26).



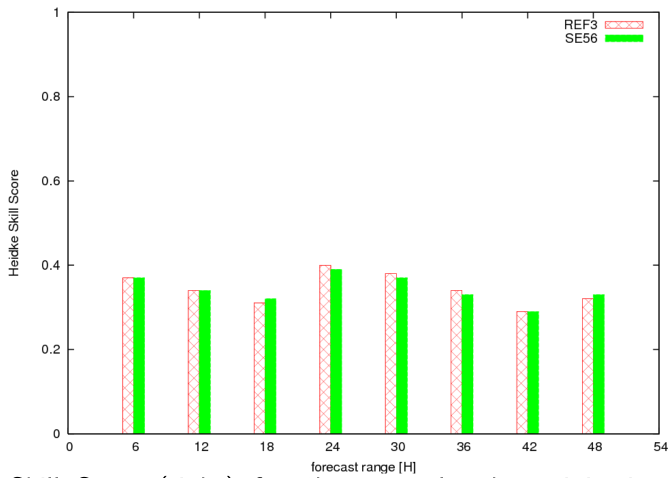


Fig. 26: Overall Percent Correct (left) and Heidke Skill Score (right) for 6h accumulated precipitations from 20060828 till 20060923 of 00 UTC runs. Reference REF3 as in red and SEVIRI run SE56 in green color.

As well as in scores by categories there were very small differences, e.g. Fig. 27-28 for no-rain category. The most noticeable differences appears for category $> 10mm$ (see Fig. 29-30) where assimilation of SEVIRI data improved skill of POD, FAR and HSS for almost all forecast ranges, but for +12H and +42H only at the cost of increasing precipitation frequency bias, in other words overestimation of rainy events for this category.

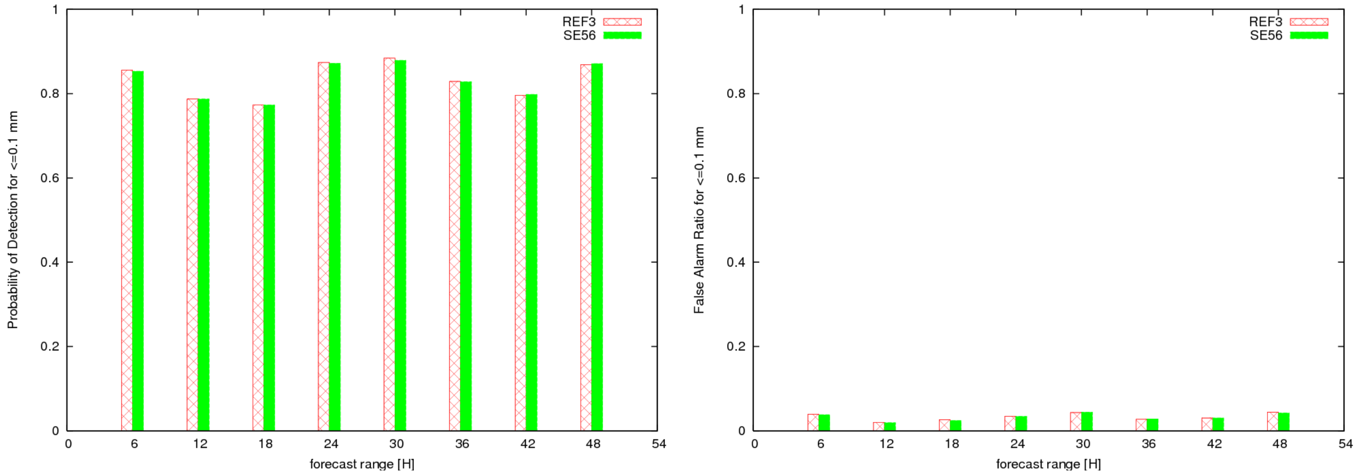


Fig. 27: POD (left) and FAR (right) for 6h accumulated precipitation $<= 0.1mm$, Reference REF3 as in red and SEVIRI run SE56 in green color.

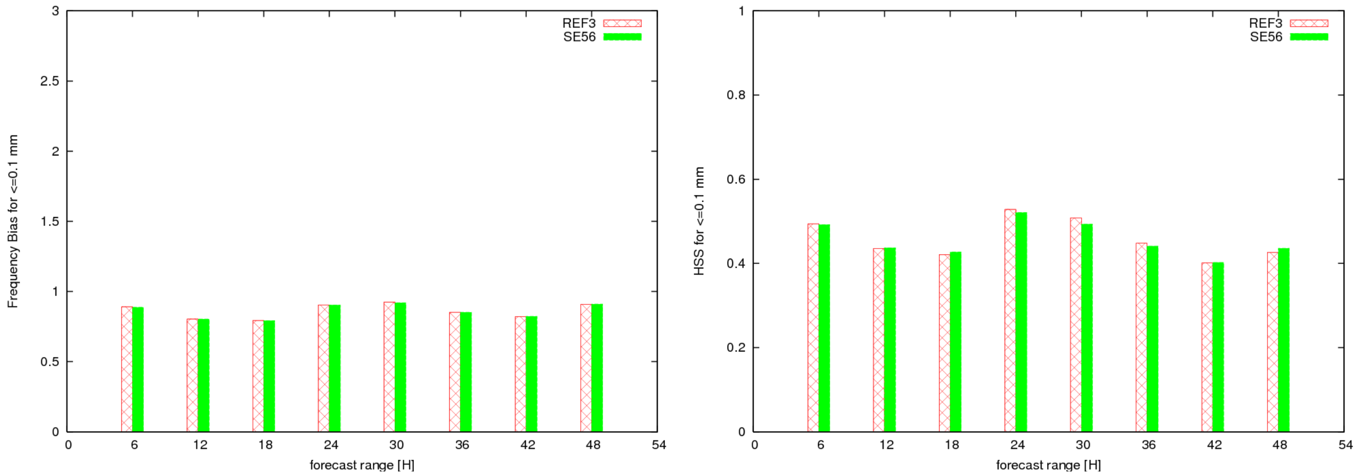


Fig. 28: B (left) and HSS (right) for 6h accumulated precipitation $<= 0.1mm$. Reference REF3 as in red and SEVIRI run SE56 in green color.

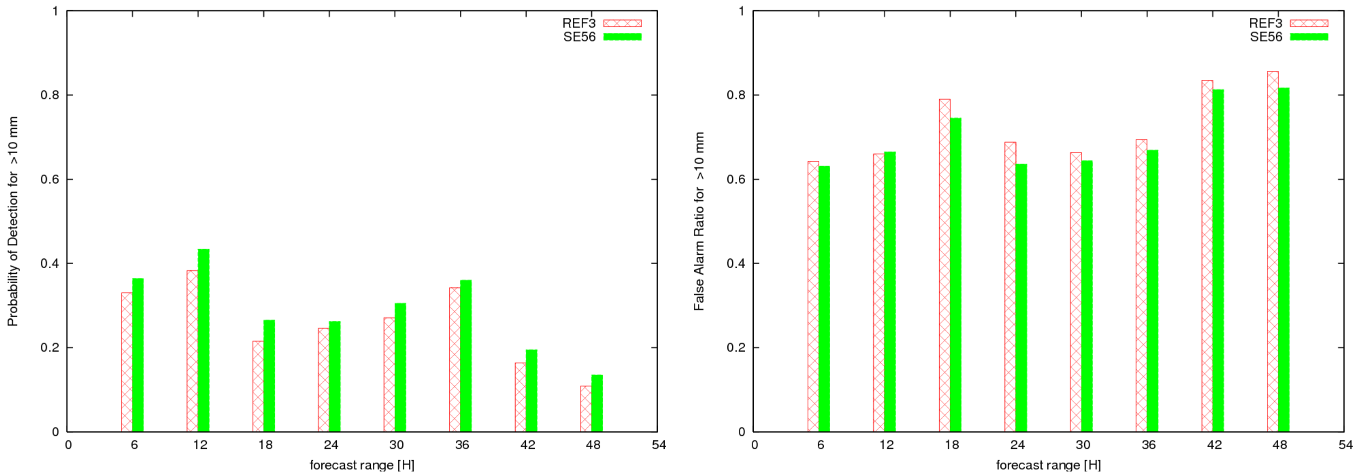


Fig. 29: POD (left) and FAR (right) for 6h accumulated precipitation $> 10mm$. Reference REF3 as in red and SEVIRI run SE56 in green color

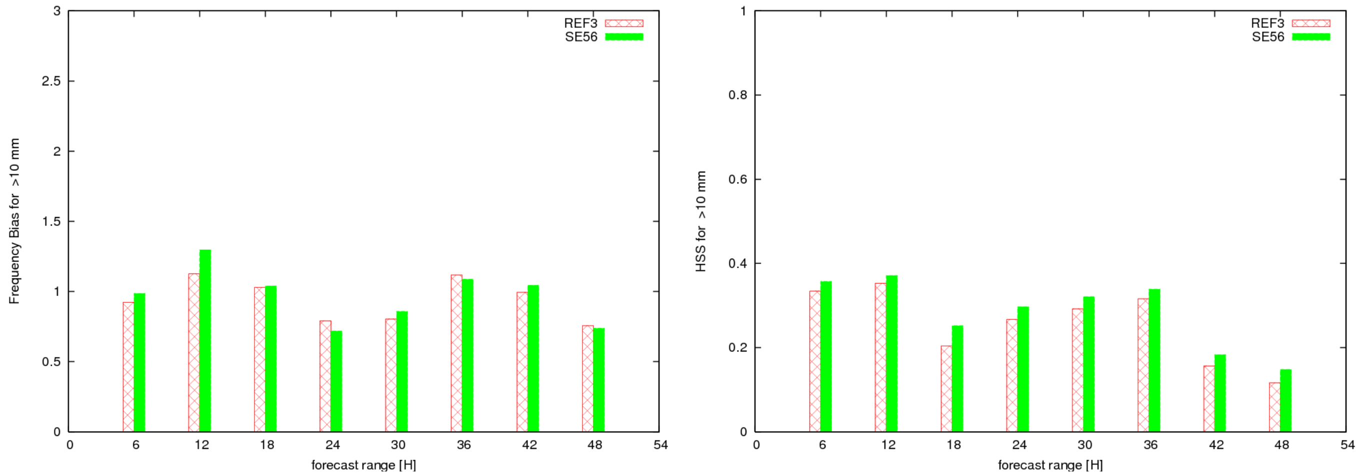


Fig. 30: B (left) and HSS (right) for 6h accumulated precipitation $> 10mm$, Reference REF3 as in red and SEVIRI run SE56 in green color

Concerning RMSE and BIAS scores there is apparent degradation for the first +12H forecast and improvement mostly for the second day (see Fig. 31).

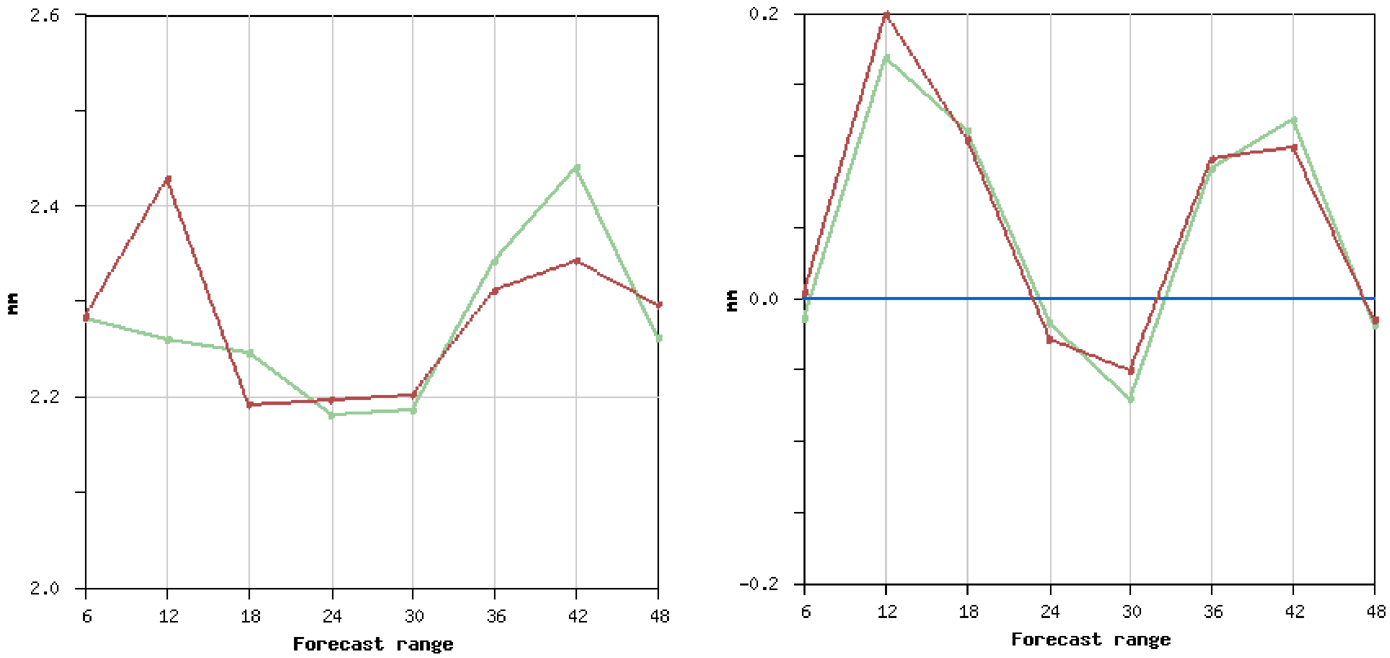


Fig. 31: RMSE (left) and BIAS (right) for 6h precipitation for productions from 20060828 00 UTC till 20060923 00UTC. Reference run REF3 in green and SEVIRI run SE56 in brown.

Impact of σ_o tuning for SEVIRI data

- **SE57** - REF3 + SEVIRI with σ_o increased by 40%
- **SE58** - REF3 + SEVIRI with σ_o decreased by 40%

in terms of RMSE and BIAS scores (see Fig. 32) the differences are small (order of 0.1 mm). Surprisingly both tuning (increase and decrease of σ_o by 40 %) slightly outperform default settings for forecast ranges +12H,+18H,+24H,+36H and +48H. The impact with respect to the reference experiment (without SEVIRI data) in case of 40 % increase of σ_o showed only very little improvement in performance of SEVIRI and 40 % decrease of σ_o improved RMSE for +18H till +48H, but degraded the first 12H forecast which is quite undesirable.

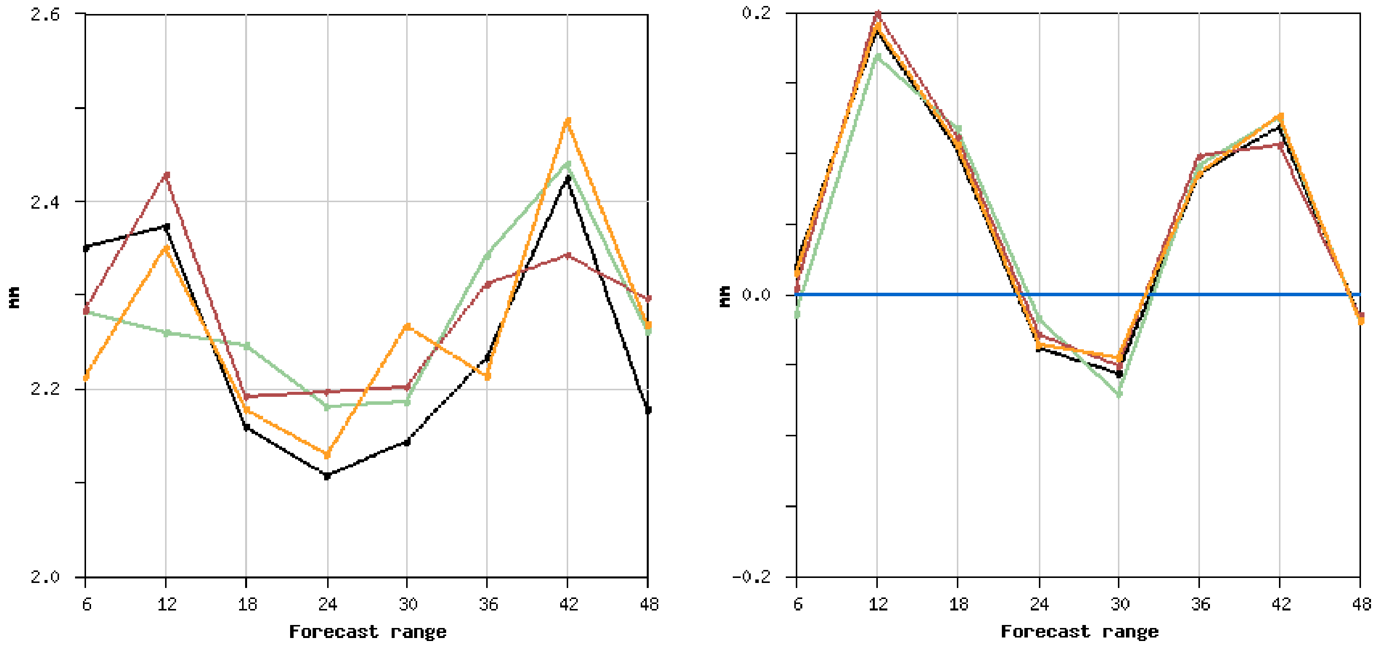


Fig. 32: RMSE (left) and BIAS (right) for 6h precipitation. Reference run REF3 in green and SEVIRI run SE56 in brown, SE57 (σ_o+40%) in yellow and SE58 (σ_o-40%) in black color.

Overall PC and HSS scores on Fig. 33 showed very small differences (e.g. for +18H overall $PC_{REF3} = 73.2\%$,$PC_{SE58} = 74.1\%$, $PC_{SE56} = 73.6\%$, $PC_{SE57} = 73.7\%$). In the precipitation scores for each category there were almost no differences in no-rain category and more noticeable for larger amount of precipitation (see Fig. 34-35) for category $> 10mm$.

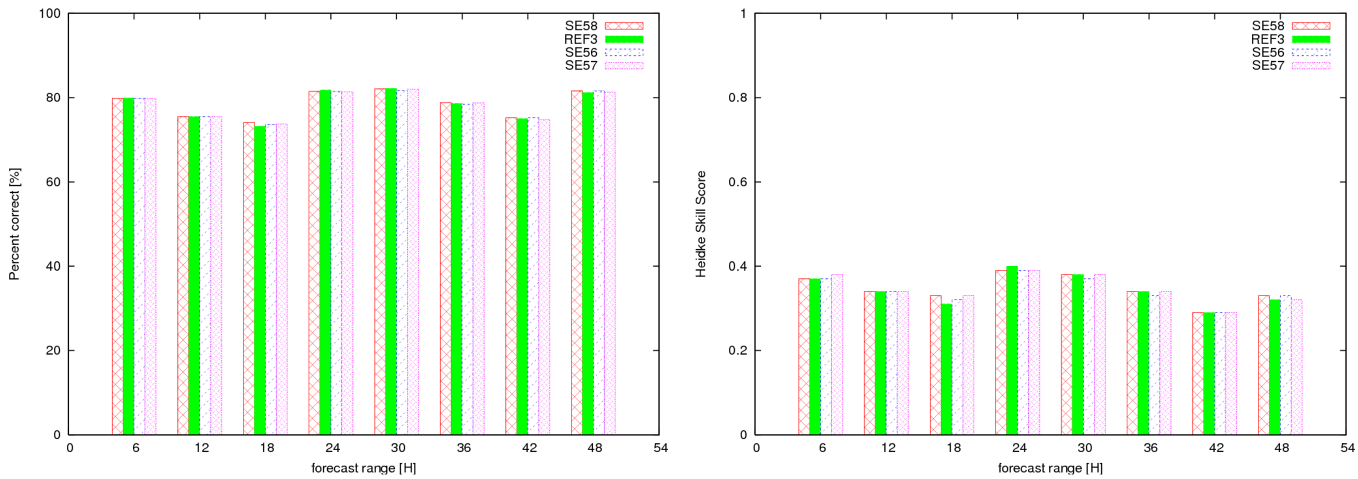


Fig. 33: Overall Percent Correct (left) and Heidke Skill Score (right) for 6h accumulated precipitations. REF3 as in green and SEVIRI runs SE56 in blue, SE57 (σ_o+40%) in violet and SE58 (σ_o-40%) in red color

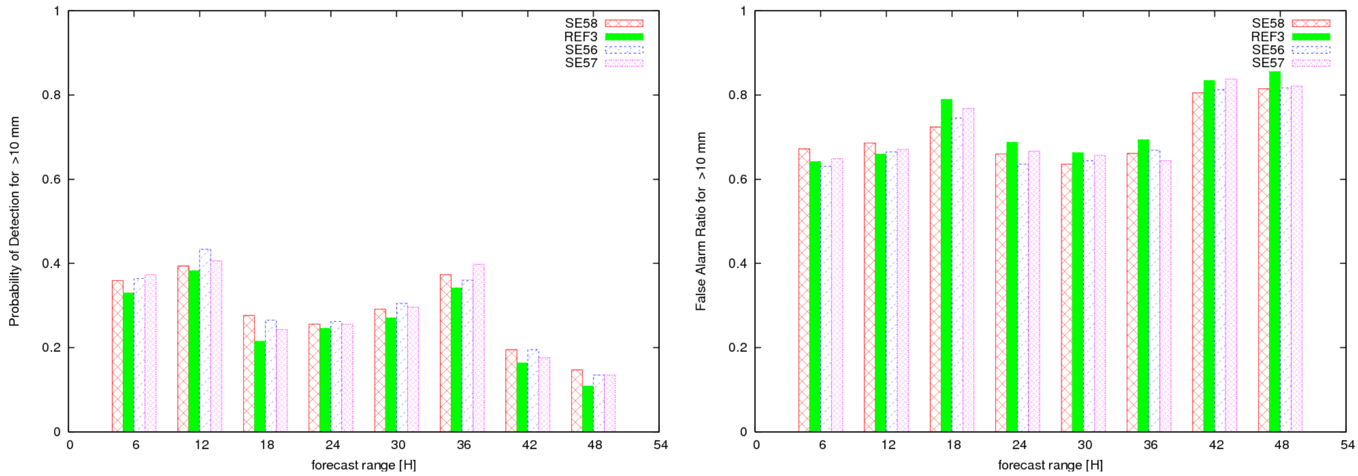


Fig. 34: POD (left) and FAR (right) for 6h accumulated precipitation $> 10mm$. Reference REF3 as in green and SEVIRI runs SE56 in blue, SE57 (σ_o+40%) in violet and SE58 (σ_o-40%) in red color

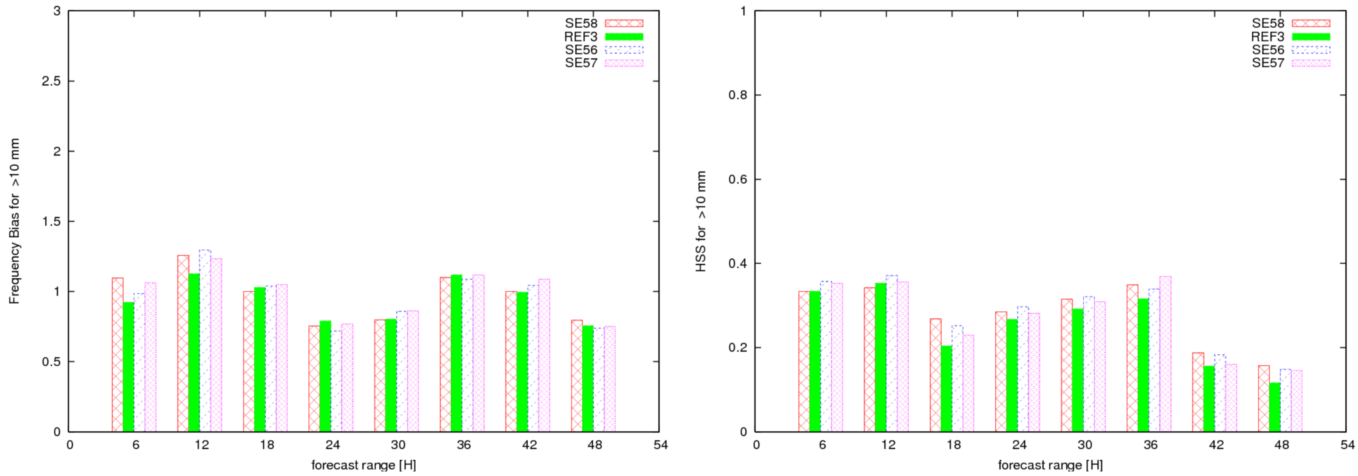


Fig. 35: B (left) and HSS (right) for 6h accumulated precipitation $> 10mm$. Reference REF3 as in green and SEVIRI runs SE56 in blue, SE57 (σ_o+40%) in violet and SE58 (σ_o-40%) in red color

3.2 Impact of different observation types against dynamical adaptation on precipitation

As next an impact of assimilation of different observation types with respect to dynamical adaptation was evaluated. Different observations were added to the 3DVAR data assimilation system in following order:

- SYNOP, TEMP observations - **REF4**
- SYNOP, TEMP, AMDAR, ATOVS, AMV observations - **REF3**
- SYNOP, TEMP and SEVIRI observations - **SE50**

In terms of RMSE scores for the first 12H any data assimilation is better than dynamical adaptation, while for +18 to +30 dynamical adaptation is slightly better, see Fig. 36. Skills of data assimilation can be demonstrated on precipitation scores as overall PC and HSS, see Fig. 37. There is obvious clear impact of SYNOP (only ϕ) and TEMP observations for the first 12H and less pronounced for other observations. There are very small differences between REF3 and SE50, which confirmed previous results, that impact of SEVIRI data is similar to that of ATOVS, AMDAR and AMV. Positive impact of overall PC score is coming mainly from the first two categories (< 0.1mm and < 2 mm) and HSS approve an improvement in all categories due to assimilation of observation. Assimilation of any selected observations improved also frequency bias - prediction of rain events no matter its accuracy - in almost all categories.

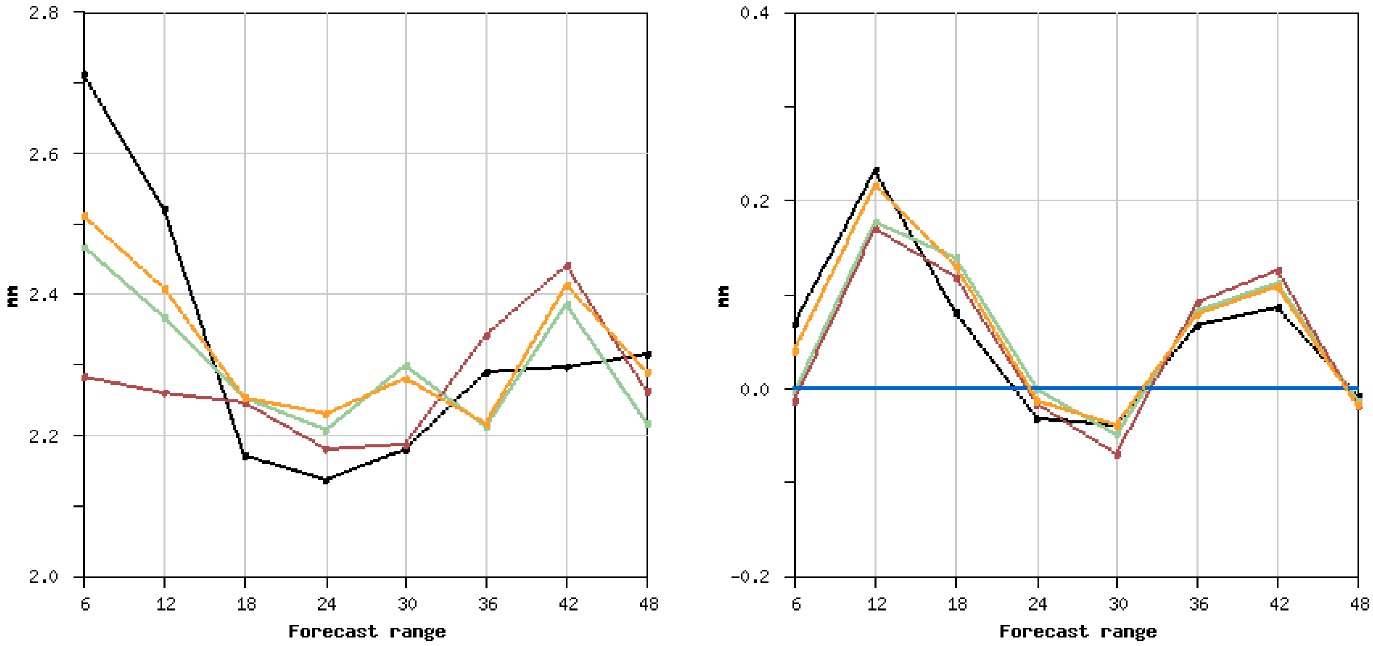


Fig. 36: RMSE (left) and BIAS (right) for 6h precipitation for productions from 20060828 00 UTC till 20060923 00UTC, Reference run REF4 (SYNOP+TEMP) in green and REF3 (SYNOP+TEMP+AMDAR+ATOVS+AMV) in red, SE50 (SYNOP+TEMP+SEVIRI) in yellow and DYNA in black color.

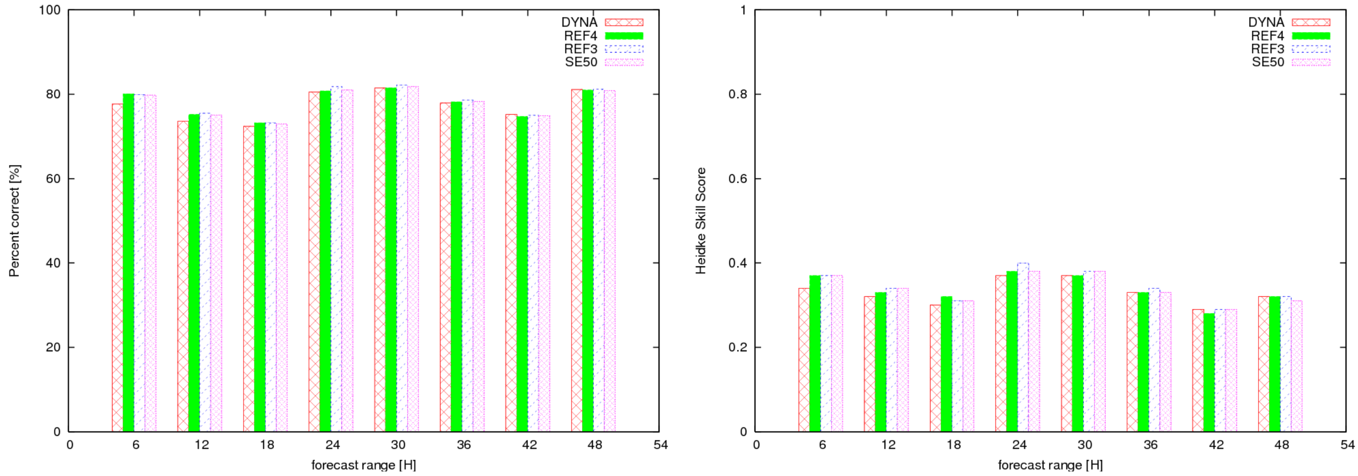


Fig. 37: Overall Percent Correct (left) and Heidke Skill Score (right) for 6h accumulated precipitations, Reference REF4 (SYNOP+TEMP) as in green, REF4 (+AMDAR+ATOVS+AMV) in blue, SE50 (REF4+SEVIRI) in violet and dynamical adaptation in red color.

3.3 Impact of both SYNOP and SEVIRI data

Following promising results of case study described in Section 2 we evaluated combined impact of SYNOP and SEVIRI data for the same period as well. Last experiment denoted as **SS56** was compared with reference **REF3**. Not only for precipitation scores were verified, but also upper-air scores with respect to both observations and ECMWF analysis.

- **REF3** - SYNOP, TEMP, AMDAR, ATOVS, AMV observations with ensemble B matrix - reference
- **SS56** - REF3 + SEVIRI with default σ_o and SYNOP (T2m and RH2m added)

Comparison against observation SS56 vs REF3 is presented on following figures, there are small differences in terms of RMSE scores, but positive impact of SYNOP and SEVIRI data assimilation prevail. The significance test pointed mostly improvement, except degradation of $MSLP$ for the first 6H of forecast, geopotential at 1000hPa at +6H and RH at some higher levels. All results of significance test is summarized in Table 1.

The most spectacular improvements are for $T2m$ and $RH2m$, see Fig. 40, which is an important result, because SEVIRI data alone provide undesirable degradation mostly for near surface parameters, combining SEVIRI with SYNOP observations we eliminated this degradation except for $MSLP$.

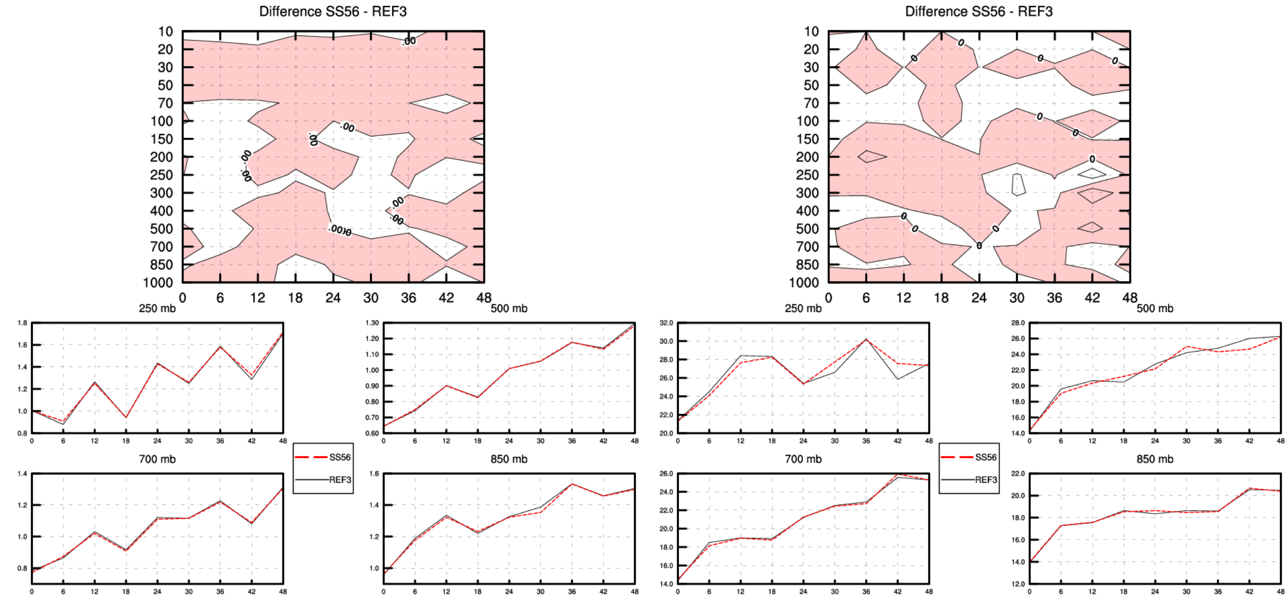


Fig. 38: RMSE of T (left) and RH (right) red areas denote **positive** impact of use SYNOP and SEVIRI observation.

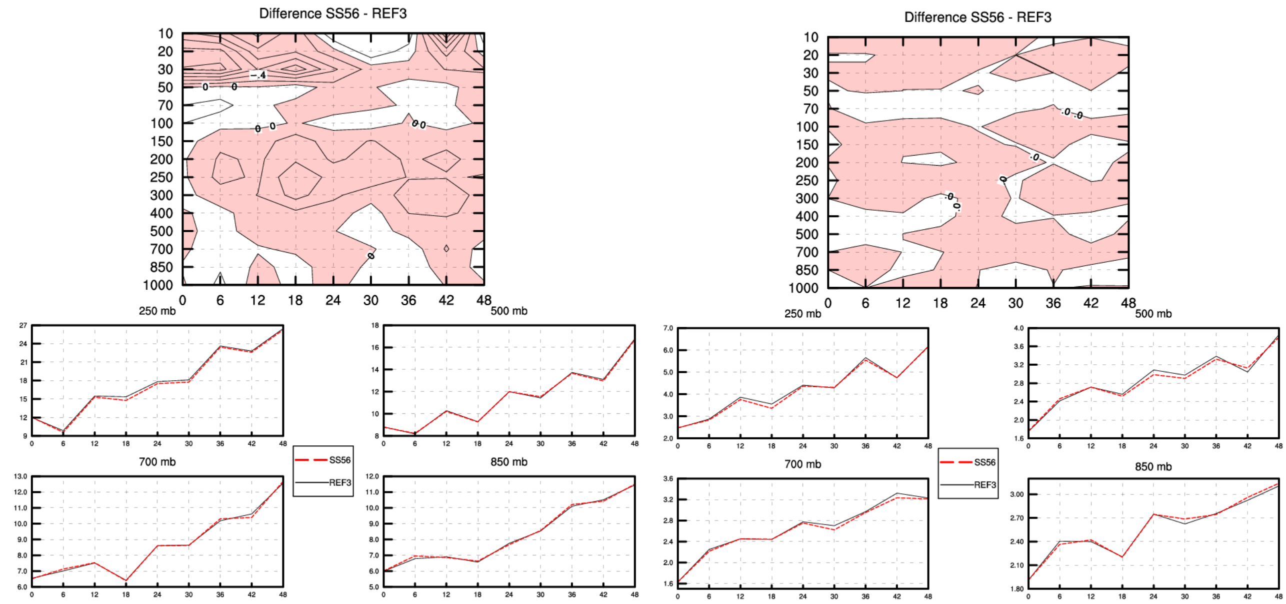


Fig. 39: RMSE of ϕ (left) and wind (right) red areas denote **positive** impact of use SYNOP and SEVIRI observation.

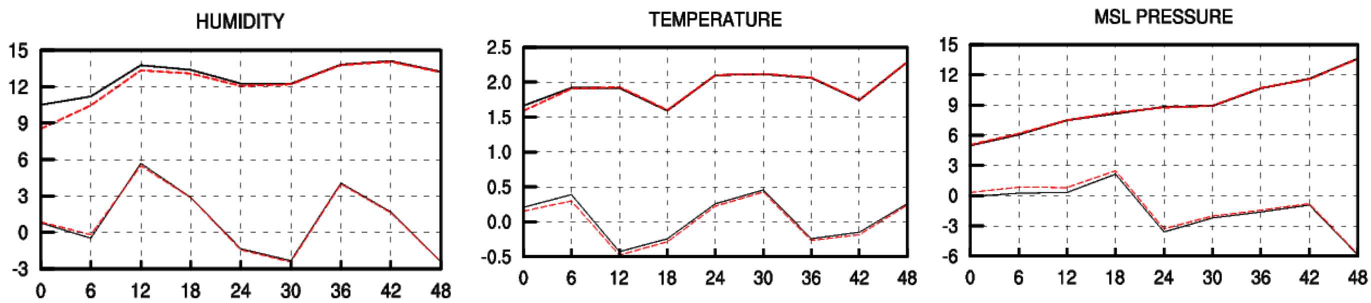


Fig. 40: RMSE and BIAS of $RH2m$ (left), $T2m$ (middle) and $MSLP$ (right) experiment SS56 with SYNOP and SEVIRI observation is in red color and reference in black.

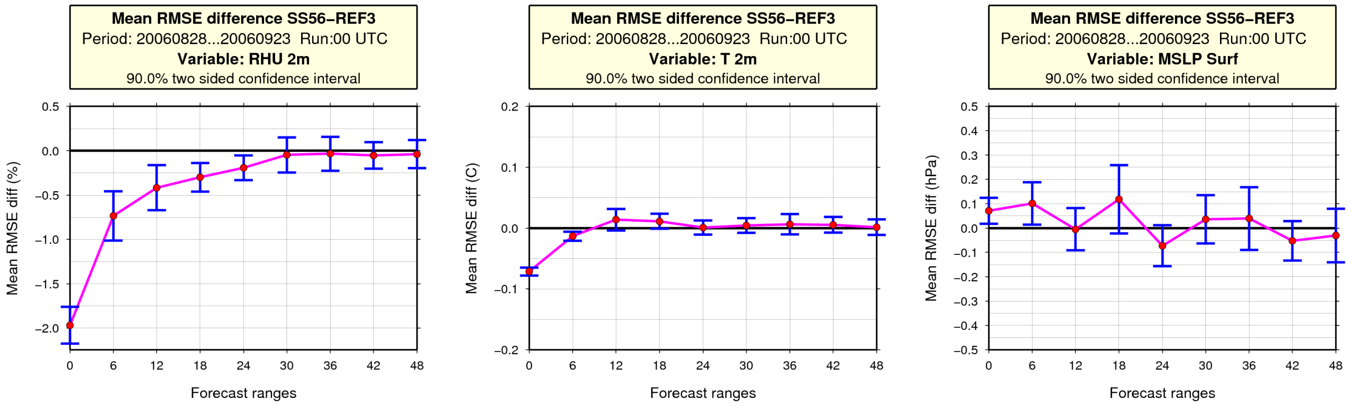


Fig. 41: Difference of RMSE scores of the 00 UTC forecasts of SS56 with SYNOP and SEVIRI observation and reference REF3. Bar shows significance 90 % two side confidence interval significance test.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+00H	**better**	T 850 hPa	+12H	**better**
	+06H	**better**	T 700 hPa	+00H	**better**
	+12H	**better**	RH 500 hPa	+24H	**better**
	+18H	**better**		+42H	**better**
	+24H	**better**	V 500 hPa	+24H	**better**
MSLP	+00H	worse	T 400 hPa	+12H	**better**
	+06H	worse	ϕ 300 hPa	+12H	**better**
T2m	+00H	**better**		+36H	**better**
	+06H	**better**	RH 300 hPa	+12H	**better**
V 10m	+00H	**better**	V 300 hPa	+36H	**better**
ϕ 1000 hPa	+06H	worse	ϕ 250 hPa	+12H	**better**
	+12H	**better**		+18H	**better**
	+24H	**better**		+36H	**better**
V 1000 hPa	+12H	**better**	RH 250 hPa	+12H	**better**
RH 1000 hPa	+00H	**better**		+30H	worse
	+12H	**better**		+42H	worse
RH 850 hPa	+24H	worse	V 250 hPa	+12H	**better**

Table 1: List of parameters and forecast ranges where SS56 performs better/worse than REF3 in terms of RMSE scores against observation with significance 90 % two side confidence interval significance test.

Comparison against ECMWF analysis was not performed for any of previous experiments, so the results for both SE56 and SS56 experiments are discussed

- **REF3** - SYNOP, TEMP, AMDAR, ATOVS, AMV observations with ensemble B matrix - reference
- **SE56** - REF3 + SEVIRI with default σ_o
- **SS56** - REF3 + SEVIRI with default σ_o and SYNOP (T2m and RH2m added)

Again there are very small differences of RMSE in both experiments for ϕ of 0.3 m^2s^{-2}, T less than 0.5 K and for RH of 1 %. From Fig. 42 and Fig. 43 is apparent that SS56 performs slightly better than SE56, in particular for RH scores near the surface (1000hPa). As well as simple counting of significant improvements displayed as white circles on figures pleads for experiment SS56 with both SEVIRI and SYNOP data assimilated.

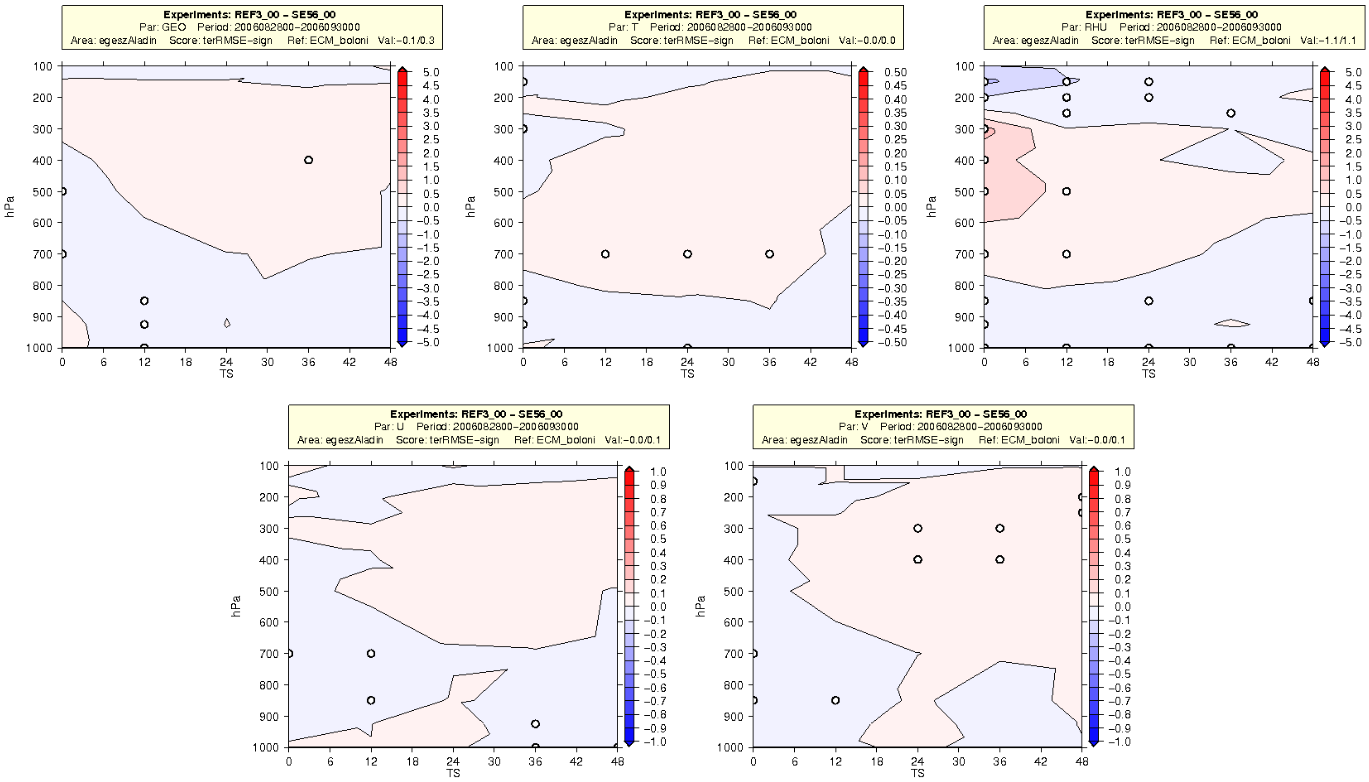


Fig. 42: Difference of RMSE scores of the 00 UTC forecasts of SE56 and REF3 shades indicate that SE56 is better, while blue shades indicate opposite. White circles show that the difference is significant on a 90 % confidence level. The figure order is the following ϕ, T, RH, u and v.

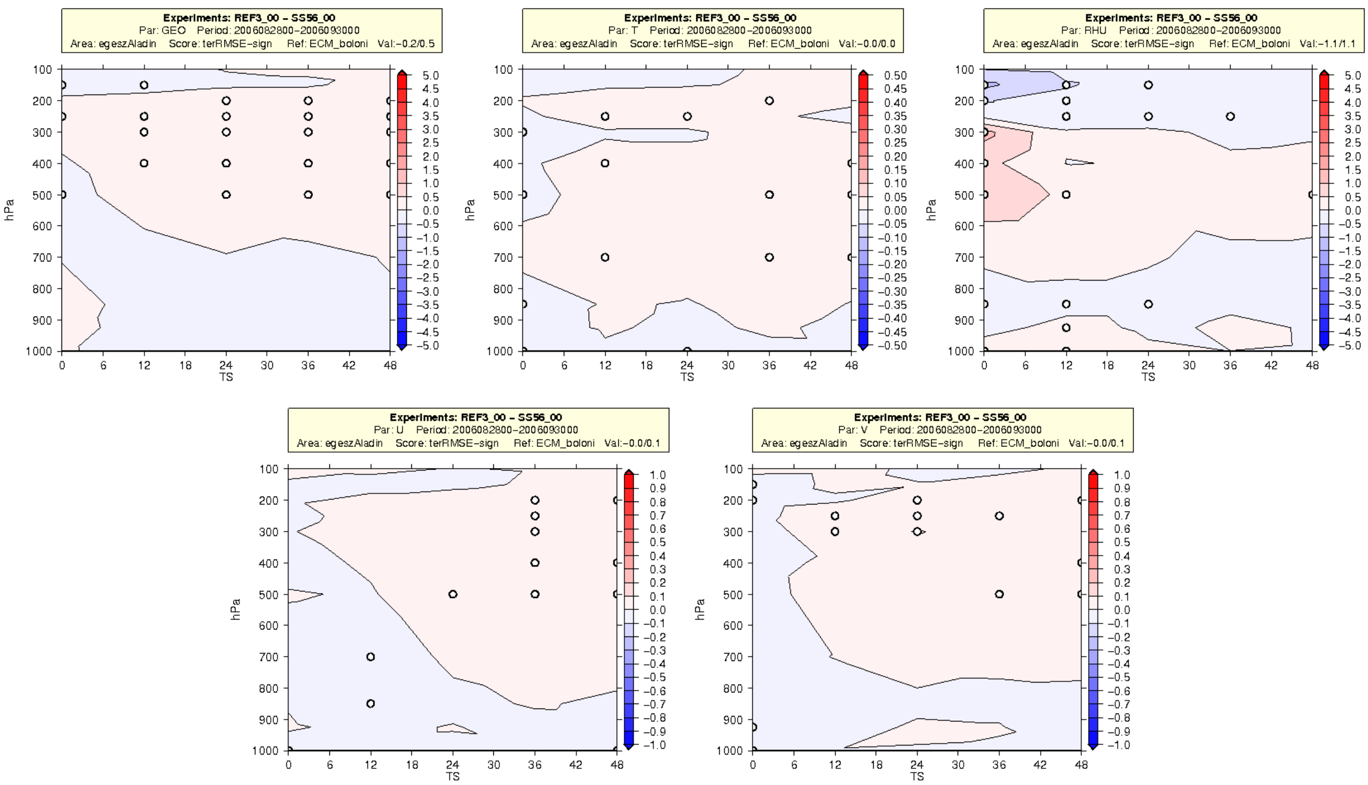


Fig. 43: Difference of RMSE scores of the 00 UTC forecasts of SS56 and REF3 shades indicate that SS56 is better, while blue shades indicate opposite. White circles show that the difference is significant on a 90 % confidence level. The figure order is the following ϕ, T, RH, u and v.

Verification scores for precipitation showed on Fig. 44 approved the skills of combined assimilation of SYNOP and SEVIRI data in terms of RMSE score. Overall PC and HSS scores showed improvement for the first 12H of the forecast, see Fig. 45. Improvement of overall HSS score is coming from scores in all categories and for overall PC score mainly from the first two categories of < 0.1 mm and < 2 mm.

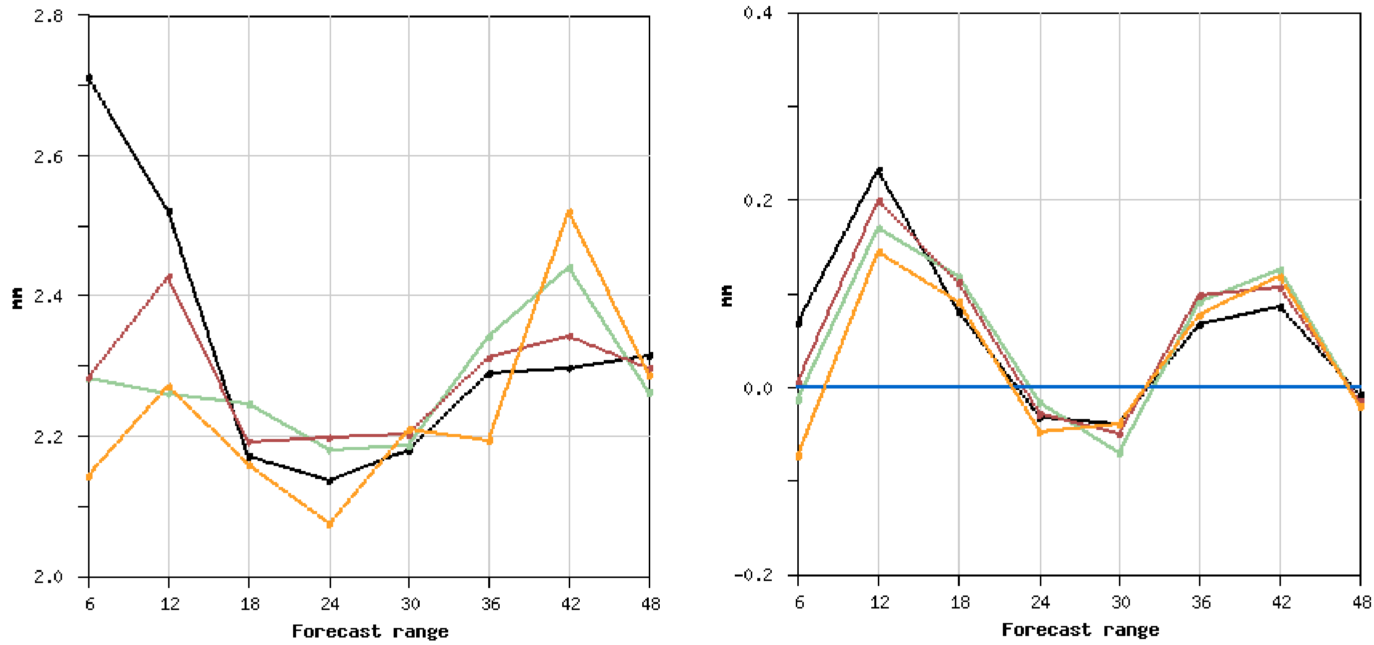


Fig. 44: RMSE (left) and BIAS (right) for 6h precipitation, Dynamical adaptation in **black**, reference REF3, SEVIRI run SE56 and both SYNOP and SEVIRI run SS56.

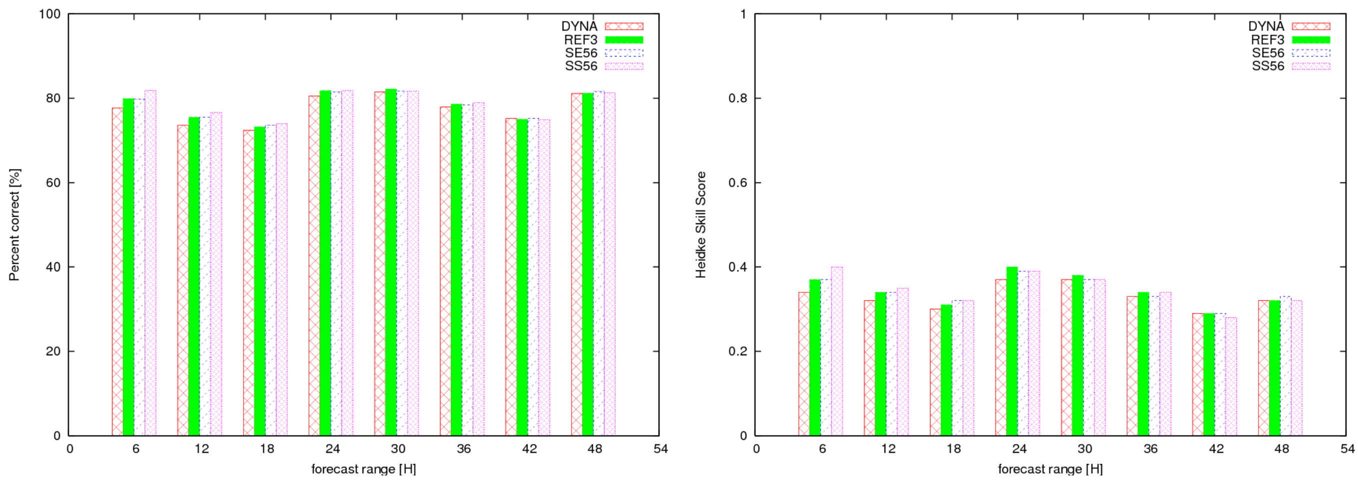


Fig. 45: Overall Percent Correct (left) and Heidke Skill Score (right) for 6h accumulated precipitations, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color

For almost all categories frequency bias of SS56 improved with respect to reference REF3 and also SE56, which denote impact of SEVIRI data alone. POD and FAR scores showed on Fig. 46- Fig. 53. confirmed skills for most of the ranges in all categories.

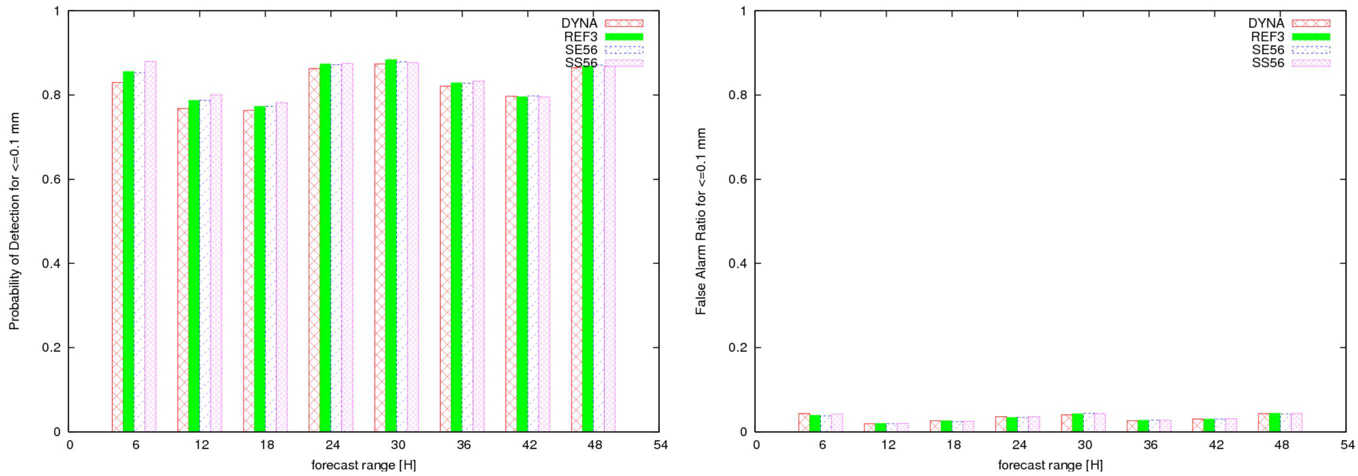


Fig. 46: POD (left) and FAR (right) for 6h accumulated precipitation $<= 0.1mm$, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color

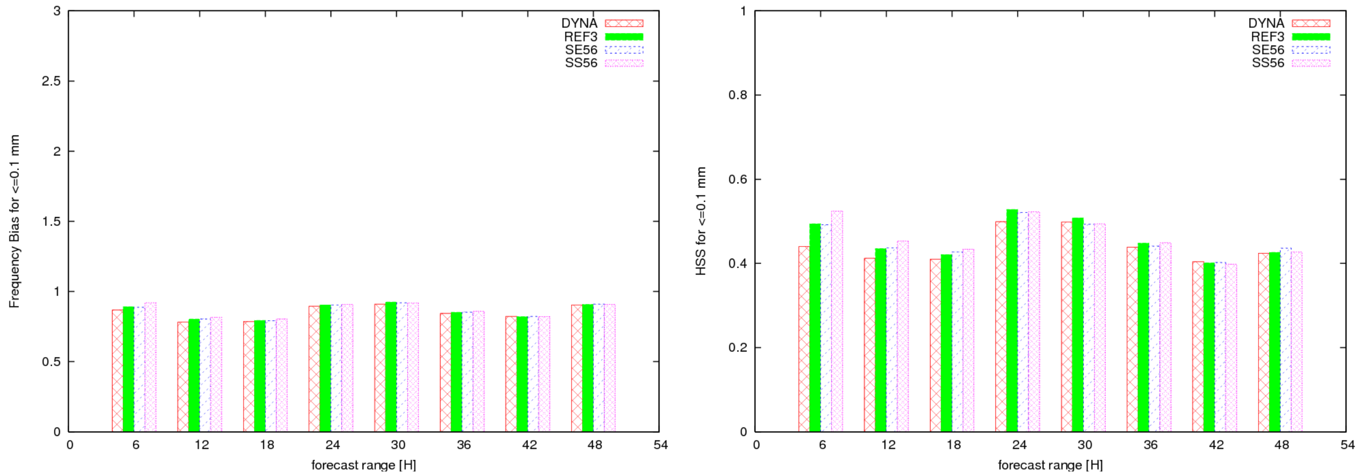


Fig. 47: B (left) and HSS (right) for 6h accumulated precipitation $<= 0.1mm$, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color

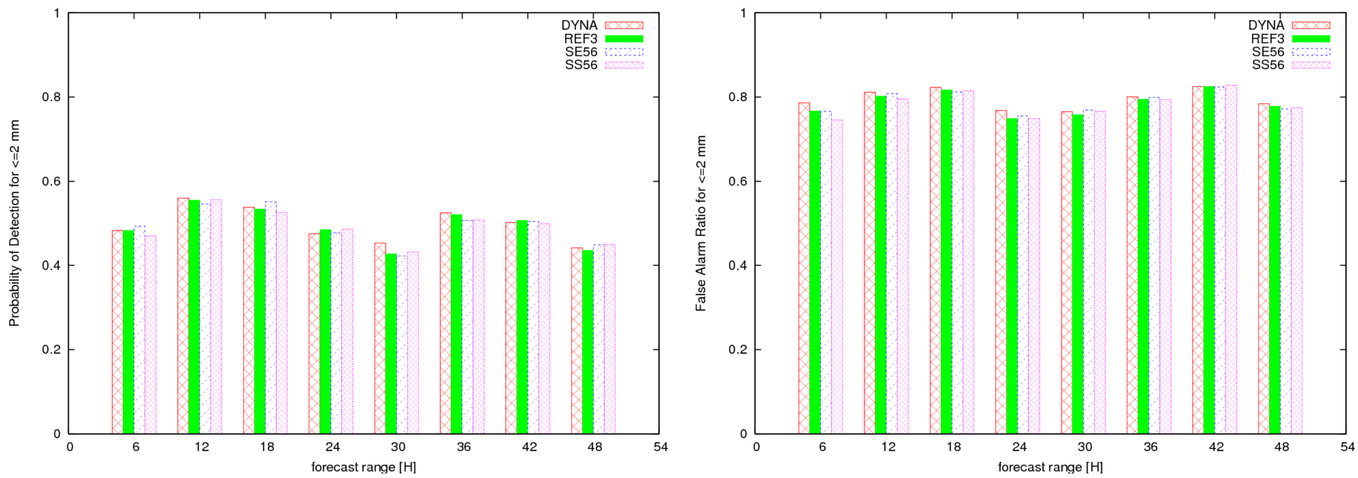


Fig. 48: POD (left) and FAR (right) for 6h accumulated precipitation $< 2mm$, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color

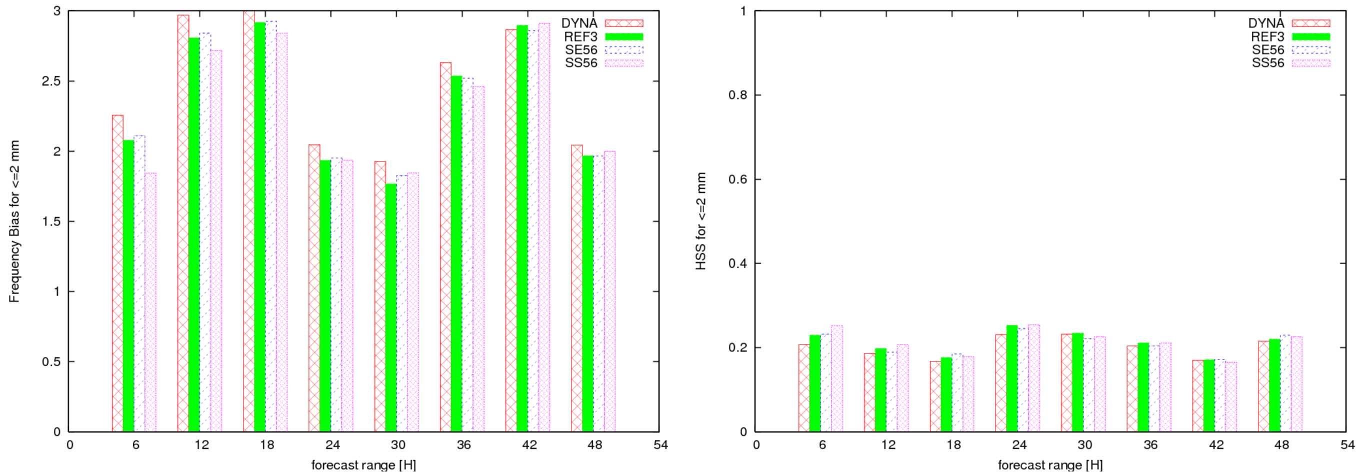


Fig. 49: B (left) and HSS (right) for 6h accumulated precipitation $< 2mm$, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color

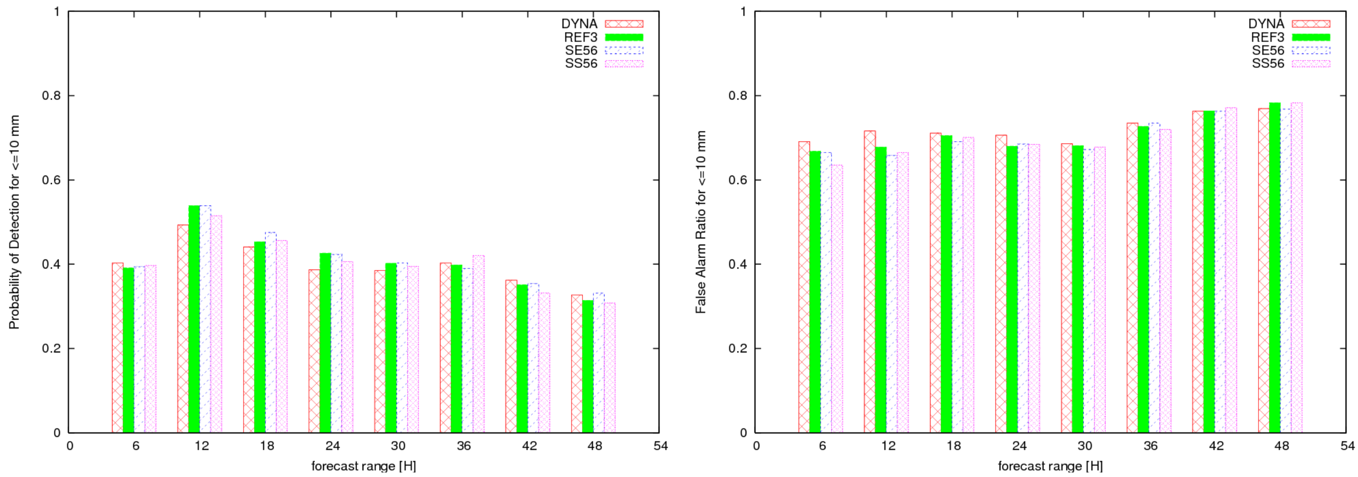


Fig. 50: POD (left) and FAR (right) for 6h accumulated precipitation $< 10mm$, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color

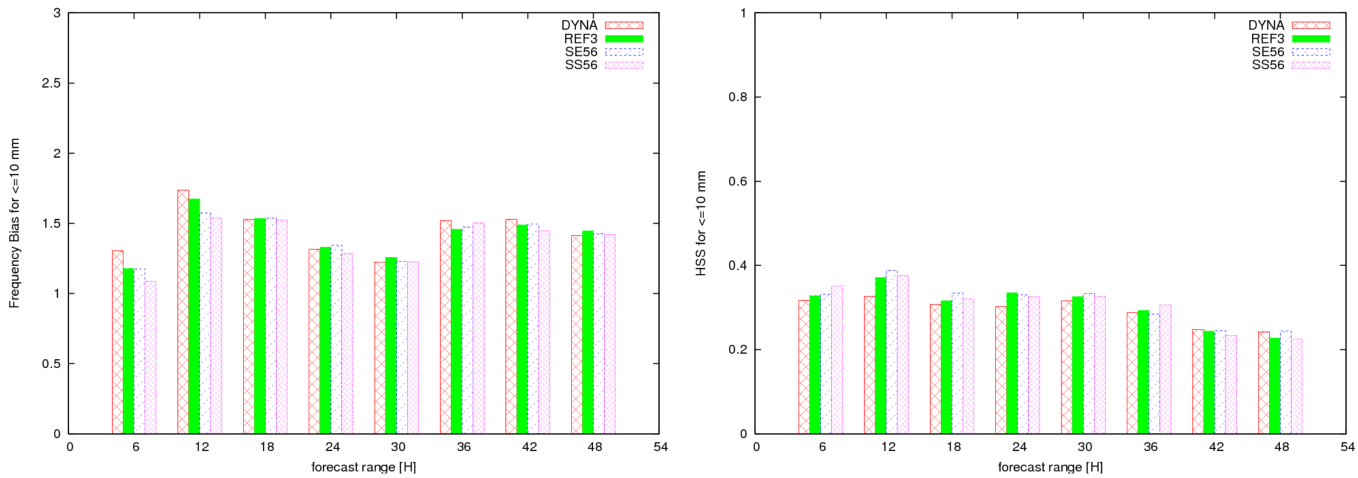


Fig. 51: B (left) and HSS (right) for 6h accumulated precipitation $< 10mm$, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color

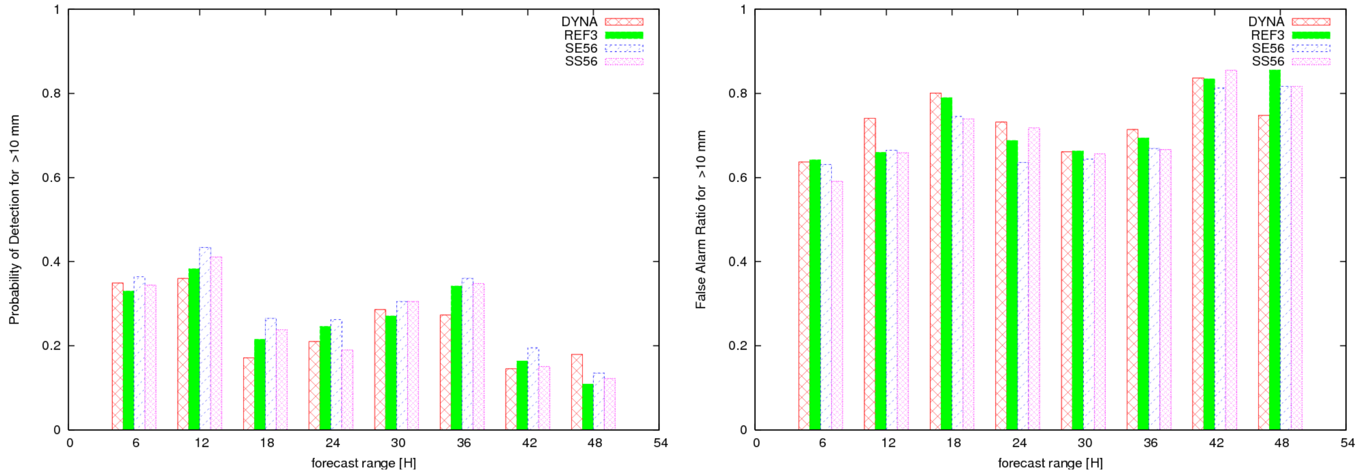


Fig. 52: POD (left) and FAR (right) for 6h accumulated precipitation $> 10mm$, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color.

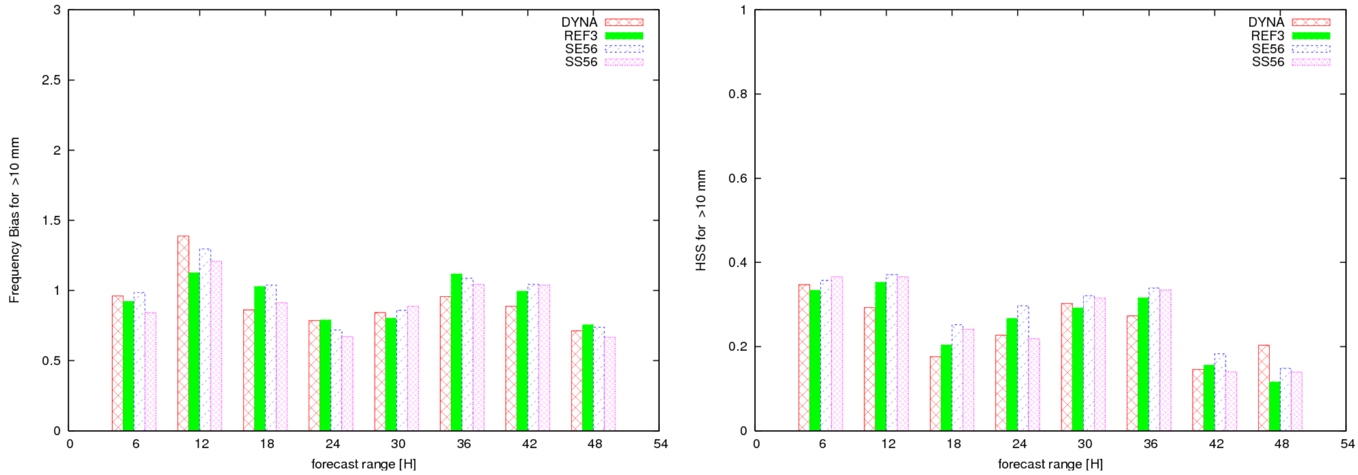


Fig. 53: B (left) and HSS (right) for 6h accumulated precipitation $> 10mm$, Reference as in green, SEVIRI experiment in blue, SYNOP and SEVIRI together in violet and dynamical adaptation in red color.

3.4 Summary

Overall precipitation scores showed very small improvement when using SEVIRI data alone independent of σ_o tuning. Evaluation of the impact on less complex data assimilation system confirmed previous results, that impact of SEVIRI data is similar to that of ATOVS, AMDAR and AMV assimilated in high resolution and that TEMP together with SYNOP ϕ observation are one of the most informative observation. Last experiments confirmed the impact of SEVIRI and SYNOP (T2m and RH2m) assimilated together in verification for longer period against observation as well as against ECMWF analysis.

4 Conclusions

An investigation of SYNOP observation behavior and an interaction with SEVIRI data on a case study is main interest of this study. Objective scores for analysis against observation showed positive impact near the surface of assimilating SYNOP observation, although this impact is almost lost after 6h forecast, generally the forecasts with assimilated SYNOP and SEVIRI observation together performs slightly better, than that of SYNOP or SEVIRI data alone (upper-air scores differences are very small, even one can say "neutral"). The evaluation of precipitation was of great importance in this study. The subjective comparison with radar over Hungary showed quantitative differences, but no qualitative improvement in any experiment. The objective scores of 6h-precipitation showed positive impact of assimilation SYNOP or SYNOP and SEVIRI data for the first 12H of forecast at least.
Impact on precipitation was completed for previous impact studies. Overall precipitation scores showed very small improvement when using SEVIRI data alone independent of σ_o tuning. Evaluation of the impact on less complex data assimilation system confirmed previous results, that impact of SEVIRI data is similar to that of

ATOVS, AMDAR and AMV assimilated in high resolution. Last experiments confirmed promising results of case study, that the skills of SEVIRI and SYNOP (T2m and RH2m) assimilated together in verification of upper-air scores both against observation and ECMWF analysis and also on precipitation scores. Based on these results pre-operational testing of SEVIRI and SYNOP (T2m and RH2m) assimilation is planned in ALADIN/HU 3DVAR system at HMS in near future.

5 Acknowledgments

The author wishes to thank Gergely Bölöni for kind supervising of my work and providing results from verification against ECMWF analysis ... The work was made possible by the financial support of the LACE (Limited Area model for Central Europe) project.

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