Study of 3D-FGAT & RUC techniques

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1 Introduction

This study is dedicated to a continuation of 3D First Guess at Appropriate Time (3D-FGAT) and more frequent cycling, so called Rapid Update Cycle (RUC) investigation and the possible combination of the two. From the 3D-FGAT studies of Kertész (2006) and Kerteśz and Bölöni (2007) a reduction of the observation minus background statistics and more observations accepted by the first guess check compared to 3DVAR are expected, but rather small differences in terms of overall verification scores. Regarding RUC, slight but clear improvements were observed by Strajnar (2006) for 3h cycling compared to 6h one. This improvements could be explained by the extra amount of observations entering the higher frequency cycling. For most of the observation types the data amount is double in 3h cycling than in 6h one, where for most of the obstypes a smaller observation window is used. All the former tests were based on summer period and this study is dedicated to a winter period only. This report is organized as follows: in Section 2 set-up of all experiments is described. In the next sections the impact of experiments are evaluated and conclusions are summarized in the last section.

2 Set-up of experiments

All experiments were based on current operational version of ALADIN/HU. More details about ALADIN/HU can be found in Bölöni (2006). Experiments include a 3D VAR or FGAT atmospheric assimilation cycling with a 6 hour or 3 hour analysis frequency. The first 3 days of assimilation were used as warm-up. LBC data are used from ECMWF. The two 48 hour forecasts starting from 00 and 12 UTC production (short cut-off) analyses were computed for testing period of 15 days from 20090117 till 20090131. Both assimilation and production analyses include local surface analysis based on optimum interpolation using SYNOP and TEMP observation. The atmospheric analysis comprises the assimilation of the following observation types: SYNOP, SHIP, TEMP, AMDAR, Wind Profilers, MSG2/GEOWIND, NOAA(15/16/17/18)/ATOVS (AMSU-A, AMSU-B and MHS). Here follows summary of ALADIN/HU main characteristics :

- ALADIN cycle 30t1
- linear grid, 8km horizontal resolution and 49 vertical levels
- domain covers roughly the same area as the formal LACE domain
- B matrix is computed with ensemble method

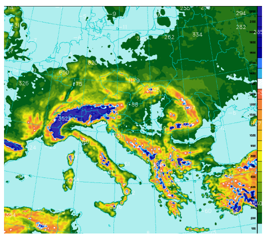


Fig. 1. The integration domain.

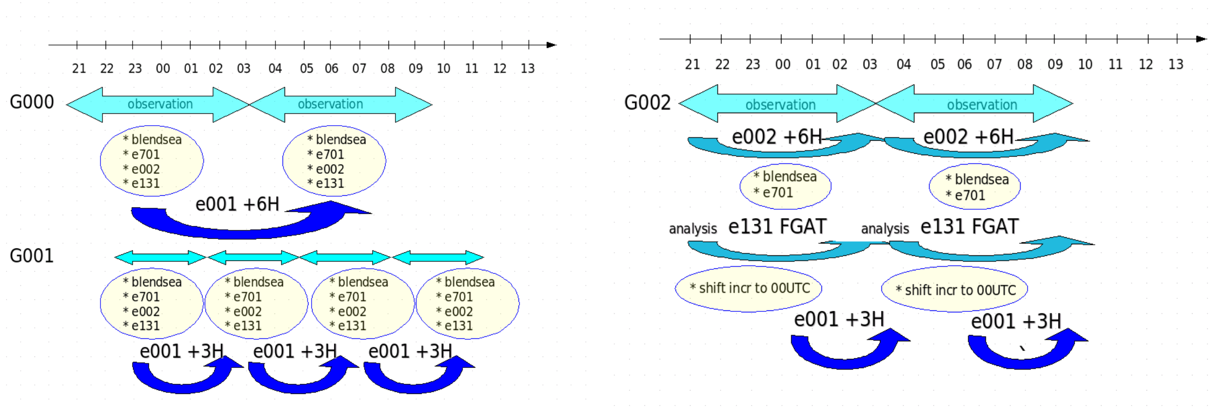
All observation were provided by OPLACE a common observation preprocessing system for LACE, for more details see Bölöni et al. (2008). The data from OPLACE are routinely downloaded at CHMI for testing purposes. The downloading is done at in real-time both for short and long cut off 6h time-window (for the timing see Table 1).

Analysis time	Short cut off	Long cut off
00 UTC	2h 30	8h 10
06 UTC	3h 20	7h 10
12 UTC	2h 10	8h 10
18 UTC	3h 20	7h 10

Table 1: Timing of real-time downloading of OPLACE observation at CHMI.

The first experiment G000 can be regarded as reference comprises a 3DVAR with 6 hour cycling, experiment G001 tested double frequency of the cycling, thus runs 3DVAR every 3 hour with shorten time-window to 3 hours. Next three experiments were dedicated to a 3D-FGAT tests, G002 with 6 hour frequency and G003 with 3 hour one. For all 3D-FGAT experiments an analysis increment was added to the background trajectory at the middle of the observation window following Kertész (2006) and the surface analysis was performed in the middle of the observation window as well. We faced technical difficulties to run an additional filtering of AMDAR data before screening, so called AMDAR filter, for 3D-FGAT configuration, so this procedure was skipped and as a consequence more aircraft data will be available in 3D-FGAT experiments. For clean evaluation of the 3D-FGAT a new 3DVAR reference experiment was recomputed without AMDAR filter and this reference will be referred as G005. In all model integration (including screening) the same digital filter initialization (DFI) was used. Due to technical problem to write and read a proper date of history files with half-an-hour frequency and also due to availability of LBCs file only every 3h a specific treatment was used in 3h 3D-FGAT. The 3h 3D-FGAT experiment is almost the same as 6h one, at first runs a 6 hour screening, after uses its 3 hour integration as guess for the surface analysis, then 3D-FGAT minimization lunches and the increment is added to the background trajectory at the middle of the observation window. The 3 hour specifics are only LBCs at 03, 09, 15 and 21 UTC and 3 hour observation window. More frequent cycling brought also one simplification for 3h 3D-FGAT, where a guess creation could be skipped and an analysis was used as starting point of subsequent assimilation cycle. Here follows a summary of performed experiments, which are also schematically displayed on Fig 2.:

- G000 - 6h 3DVAR (with AMDAR filter)
- G001 - 3h 3DVAR (with AMDAR filter)
- G002 - 6h 3D-FGAT without AMDAR filter
- G003 - 3h 3D-FGAT without AMDAR filter
- G005 - 6h 3DVAR without AMDAR filter



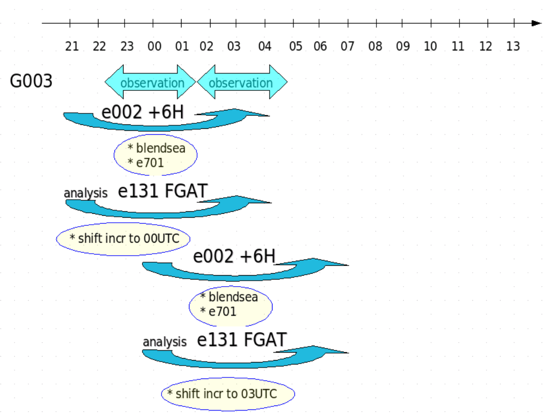


Fig. 2. Schematic display of tested configurations. The 3DVAR every 6 hour and every 3 hour (top-left), the 3D-FGAT every 6 hour (top-right) and the 3D-FGAT every 3 hour (bottom). In both 3D-FGAT experiments an analysis increment is added to the background trajectory at the middle of the observation window where also the surface analysis was performed.

3 Impact of more frequent 3DVAR cycling

In this section an impact of more frequent 3DVAR cycling will be evaluated.

3.1 Observation overview

Observation in OPLACE are provided in hourly intervals defined as +/- 30 min around given hour, so called time-slots. The reference experiment G000 use SYNOP, TEMP, SATOB and wind-profiler data from the single time-slot valid at analysis time, AMDAR from three middle times slots and SATEM from all seven time slots within 6H time-window. The 3h 3DVAR experiment G001 uses SYNOP, TEMP, SATOB and wind-profiler data from the single time-slot valid at analysis time and AMDAR and SATEM from three middle times slots, which cover the 3 hour time-window. Thus double amount of SYNOP, AMDAR, SATOB and wind-profiler data and the same number of TEMP and SATEM observation were expected for 3h 3DVAR experiment. Observation statistics from all assimilation runs of 6h and 3h 3DVAR from period 20090114-20090131 are summarized in Table 2. The statistics confirmed expectation of almost double SYNOP, AMDAR and SATOB increase, the same number of TEMP observation, but quite suspicious is 360-400% increase of wind profiler data. During stay a bug in observation monitoring was found in observation monitoring and/or data, thus wind profiler statistics may be corrupted. Also decrease of 10-25 % of SATEM observation total amount is unexplained. O-G mean statistics didn't show clear signal, for O-A Mean statistics and also for both standard deviations prevail smaller values for G001.

	Var	Total	Total*	Active	Active*	O-G Mean		O-A Mean		O-G STD		O-A STD	
		G000	G001	G000	G001	G000	G001	G000	G001	G000	G001	G000	G001
SYNOP	Geo	43054	193.3	42314	194.6	16.39	8.47	3.09	1.98	69.14	62.13	40.73	37.84
AIREP	T	115249	193.9	111389	194.3	0.16	0.16	0.10	0.07	1.20	1.15	0.78	0.76
	U	115249	193.9	111926	194.3	-0.02	-0.04	-0.00	-0.01	3.09	2.90	1.73	1.71
	V	115249	193.9	111926	194.3	0.07	0.10	0.03	0.03	3.23	3.00	1.76	1.72
SATOB	U	92359	204.9	12293	213.9	-0.48	-0.35	-0.16	-0.11	3.08	2.73	1.49	1.36
	V	92359	204.9	12293	213.9	-0.11	-0.22	-0.09	-0.10	2.84	2.65	1.46	1.36
TEMP	Geo	27236	100.0	25398	99.9	-1.99	-2.51	-1.42	-1.52	14.45	14.25	11.91	11.40
	T	68948	100.0	67080	100.0	-0.10	-0.09	0.01	0.01	1.40	1.39	0.93	0.92
	U	61476	100.0	59939	100.0	0.08	0.10	0.06	0.05	3.34	3.29	2.12	2.12
	V	61476	100.0	59939	100.0	-0.06	-0.10	-0.03	-0.04	3.37	3.31	2.03	2.03
	Q	61599	100.0	40448	100.0	-0.00	0.02	-0.00	-0.00	0.53	0.54	0.25	0.25
WindProfiler	U	98073	407.3	626	2193.8	0.93	0.28	-0.65	-1.43	2.17	2.20	0.92	0.81
	V	79407	366.7	466	1936.1	0.16	0.19	-0.30	-0.02	2.72	2.29	0.12	0.22
N15 AMSU-A	5	94568	79.1	3480	91.7	-0.00	-0.00	0.01	0.01	0.26	0.23	0.17	0.16
	7	94840	79.2	3950	90.5	-0.08	-0.08	-0.07	-0.07	0.22	0.17	0.16	0.14
	8	94572	79.1	13973	90.3	0.01	0.03	0.02	0.02	0.28	0.18	0.15	0.13
	9	94570	79.1	13942	90.5	-0.04	-0.01	0.00	0.00	0.36	0.25	0.16	0.15
	10	94568	79.1	13534	91.6	-0.07	-0.05	-0.01	-0.01	0.43	0.37	0.19	0.18
	12	94260	79.1	12511	90.0	0.03	0.05	0.01	0.01	1.39	1.31	0.61	0.52
N15 AMSU-B	3	856168	79.2	6266	103.4	0.29	0.23	-0.32	-0.36	3.91	3.28	1.86	1.80
	4	856090	79.2	5281	107.3	2.04	2.22	0.96	0.93	4.17	3.85	1.95	1.86
	5	856218	79.2	3870	102.2	-0.13	-0.17	-0.53	-0.57	2.78	2.53	1.42	1.40
N16 AMSU-A	8	122466	85.5	12268	99.9	-0.03	-0.05	-0.00	-0.00	0.43	0.43	0.33	0.32
	9	139750	86.6	14657	101.6	0.01	-0.02	0.01	0.01	0.39	0.34	0.21	0.21
	10	129778	85.7	12484	105.4	0.13	0.12	-0.05	-0.05	0.46	0.46	0.24	0.24
	11	140492	86.6	13190	107.3	0.40	0.35	0.29	0.26	0.69	0.74	0.37	0.39
	12	134052	86.1	12400	101.7	-0.94	-0.90	-0.72	-0.64	1.27	1.29	0.85	0.89
N16 AMSU-B	3	1294820	86.8	6903	107.3	0.26	0.06	0.10	0.10	4.37	4.04	2.20	2.14
	4	1294824	86.8	6714	107.9	-0.14	-0.30	-0.07	-0.04	3.41	3.14	1.84	1.81
	5	1294804	86.8	4002	104.3	-0.01	-0.23	-0.02	-0.07	3.38	3.32	2.20	2.17
N17 AMSU-B	3	1090605	75.8	6997	114.6	-0.07	0.08	0.12	0.11	3.54	2.80	0.98	0.85
	4	1090599	75.8	6753	115.9	-0.56	-0.41	-0.05	-0.03	3.00	2.52	0.91	0.83
	5	1090608	75.8	4007	122.9	-0.45	-0.38	-0.08	-0.04	2.40	2.17	1.07	1.02
N18 AMSU-A	5	118454	97.0	4682	96.2	0.02	0.07	0.06	0.07	0.28	0.25	0.20	0.19
	6	118454	97.0	4909	96.4	-0.14	-0.10	-0.07	-0.06	0.18	0.17	0.14	0.14
	7	118454	97.0	5317	96.2	-0.13	-0.11	-0.07	-0.07	0.23	0.21	0.17	0.16
	8	118454	97.0	20434	103.7	-0.01	0.01	0.01	0.01	0.27	0.25	0.19	0.18
	9	118454	97.0	20414	103.6	-0.05	-0.02	-0.03	-0.02	0.32	0.30	0.16	0.15
	10	118454	97.0	19410	103.6	-0.02	0.01	-0.01	-0.00	0.44	0.44	0.19	0.19
	11	118454	97.0	19204	104.1	0.01	0.01	-0.01	-0.01	0.72	0.70	0.36	0.34
	12	118454	97.0	18891	102.6	0.06	0.03	-0.05	-0.05	1.32	1.34	0.78	0.78
18 AMSU-B	3	1083033	96.8	9041	122.9	-0.10	0.16	0.10	0.09	2.98	2.50	0.78	0.68
	4	1083018	96.8	8708	123.1	-0.53	-0.32	-0.00	-0.01	2.66	2.22	0.79	0.70
	5	1083027	96.8	5092	125.7	-0.57	-0.45	-0.14	-0.12	2.32	2.09	0.97	0.90

Table 2: Observation summary for **G001** (20090114 00 UTC - 20090131 18 UTC) of all analyses. * relative difference with respect to **G000**.

3.2 Comparison against analyses

Both 00 and 12 UTC forecasts were evaluated with respect to ECMWF and ARPEGE analysis for testing period of 15 days in January 2009 and on following figures RMSE differences are displayed. White circles show that the difference is better/worse with significance 90% two-side confidence interval.

3.2.1 Comparison against ECMWF analyses

There can be found mainly positive impact in upper troposphere (especially for geopotential and humidity and generally more pronounced for 00UTC forecasts). Also there is noticeable degradation of geopotential at the end of forecast for 00 UTC.

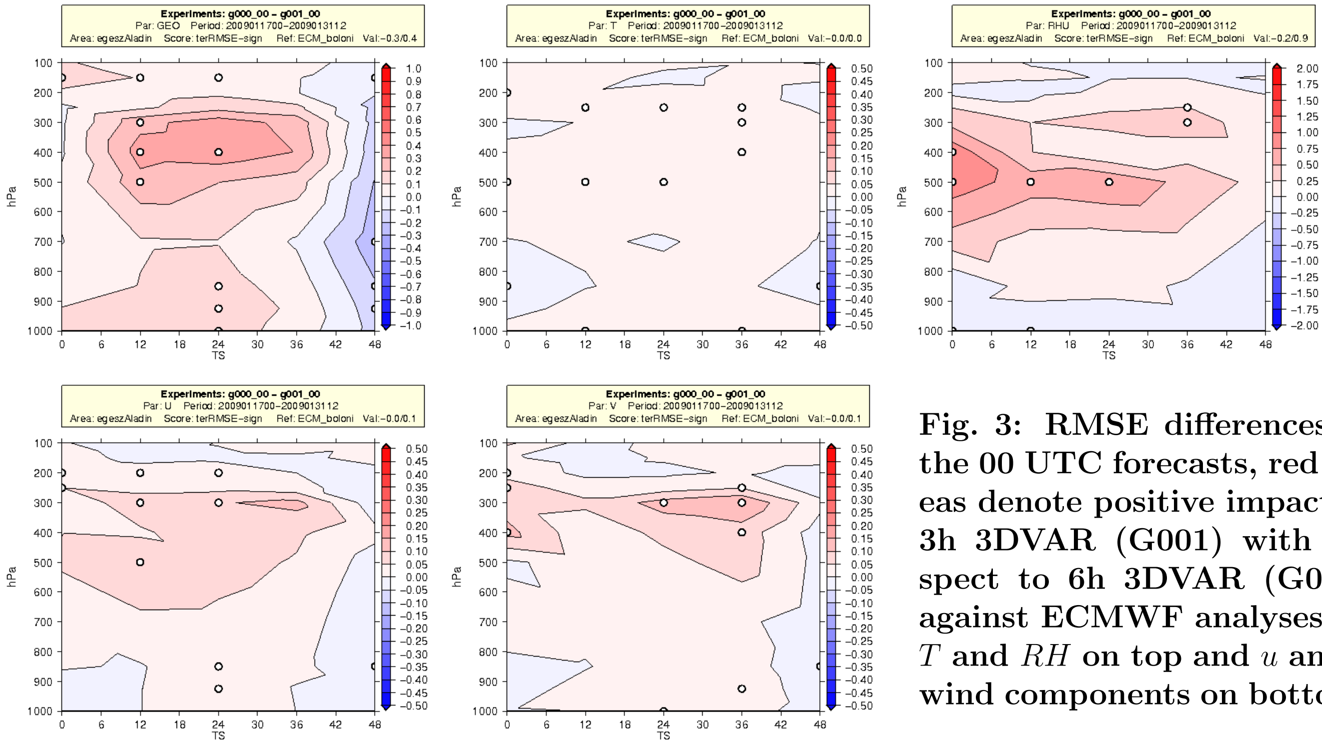


Fig. 3: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 3h 3DVAR (G001) with respect to 6h 3DVAR (G000) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

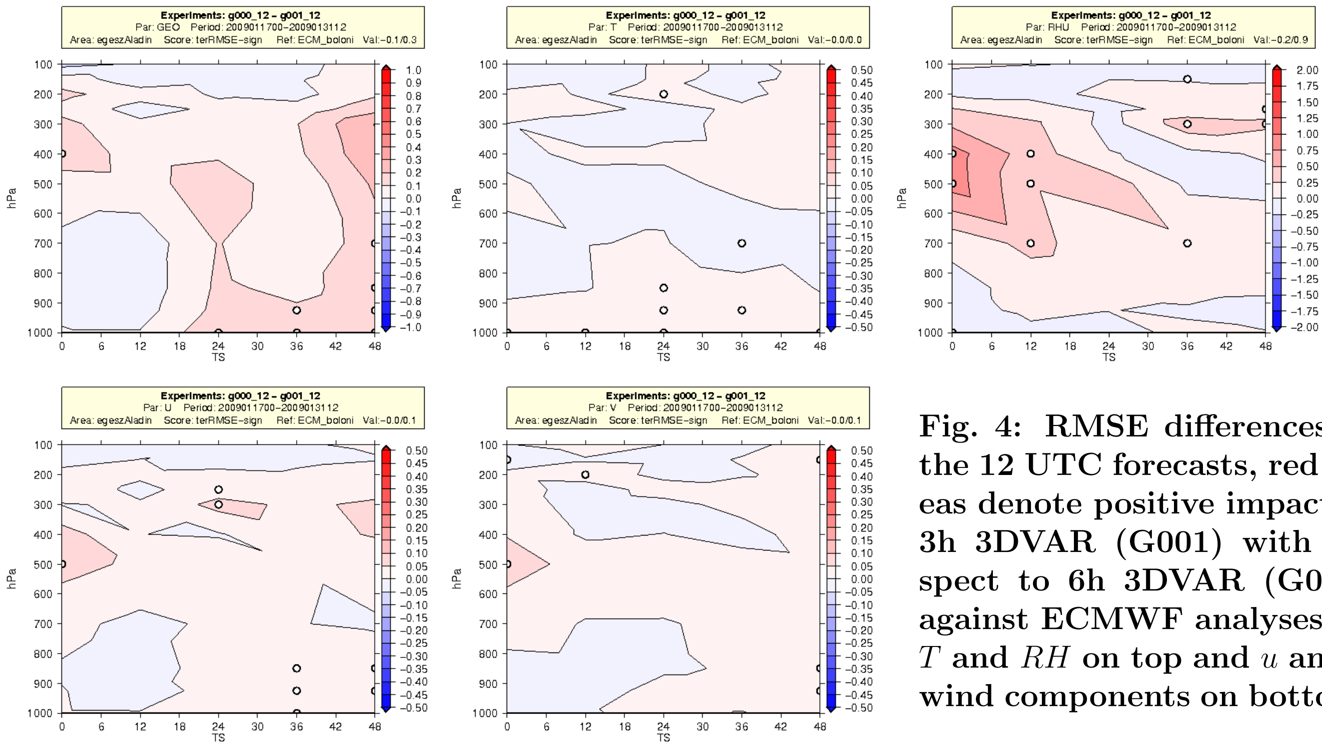
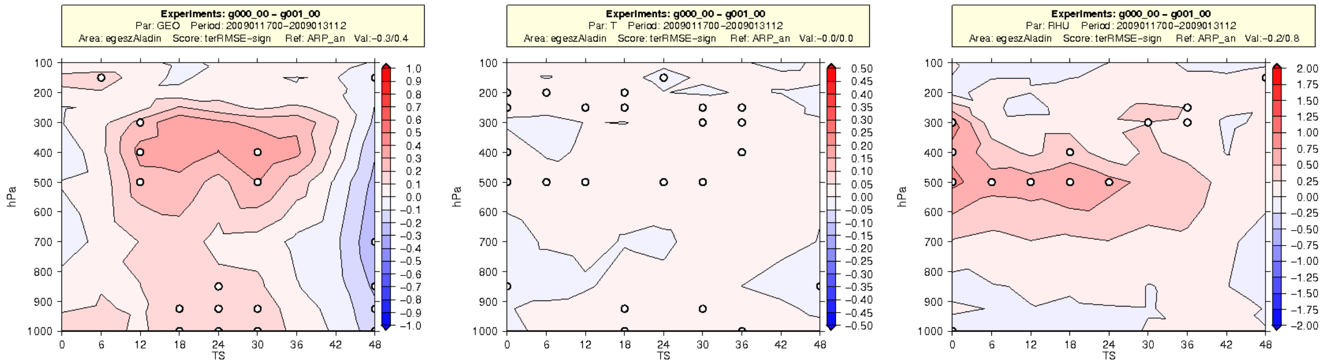


Fig. 4: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 3h 3DVAR (G001) with respect to 6h 3DVAR (G000) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

3.2.2 Comparison against ARPEGE analyses

Very similar results were obtained in evaluation with respect to independent ARPEGE analysis (note that ECMWF LBC were used in experiments).



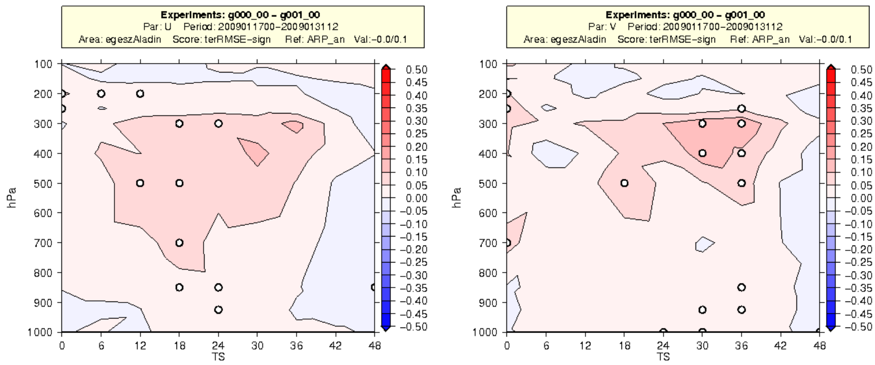
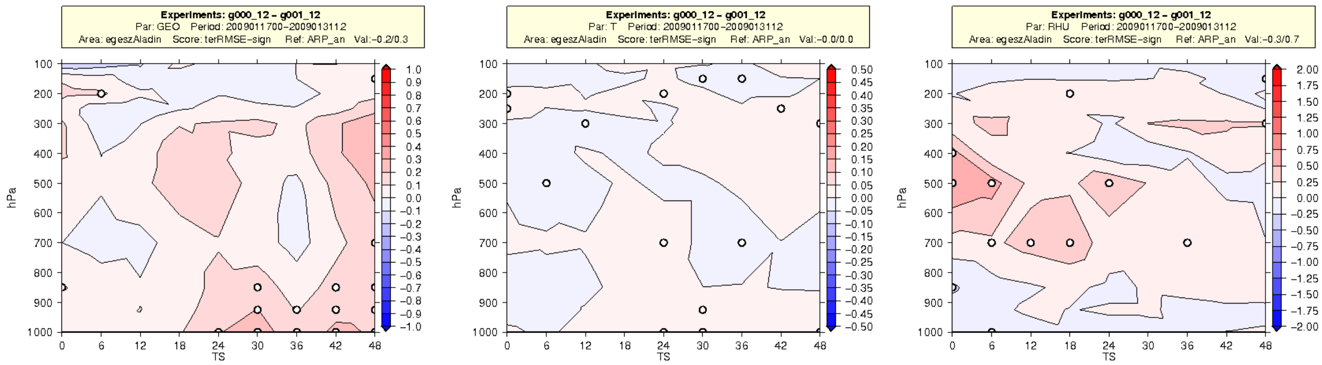


Fig. 5: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 3h 3DVAR (G001) with respect to 6h 3DVAR (G000) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.



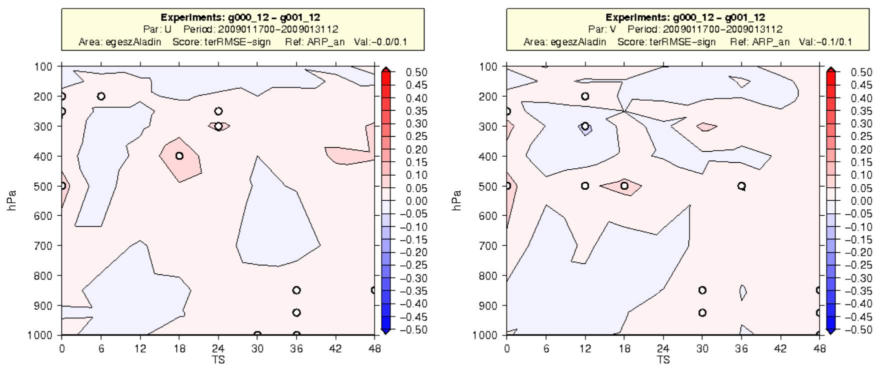


Fig. 6: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 3h 3DVAR (G001) with respect to 6h 3DVAR (G000) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.

3.3 Comparison against observation

Forecasts were evaluated with respect to SYNOP and TEMP observation as well and on following figures RMSE differences of geopotential, temperature, relative humidity and wind speed are displayed. There were found very small differences and in results of significance test, summarized on last figure, there prevail statistical improvement for lower troposphere (below 850hPa).

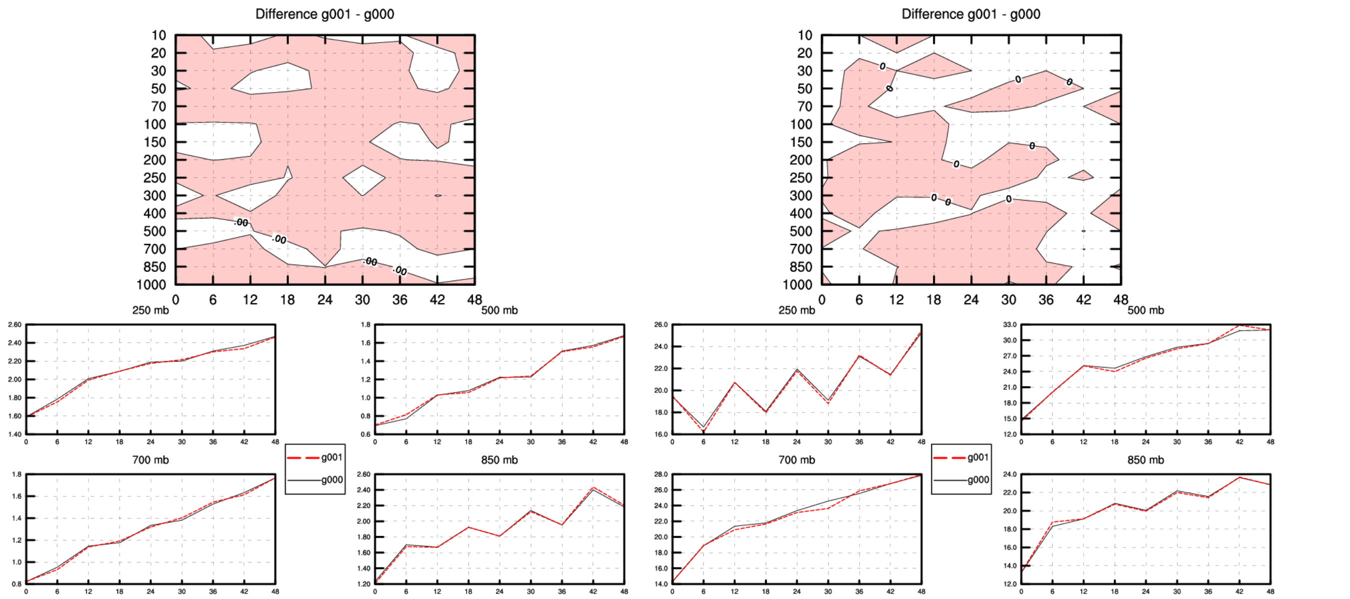


Fig. 7: RMSE of T (left) and RH (right),red areas denote positive impact of 3h 3DVAR (G001) with respect to 6h 3DVAR (G000) against observation.

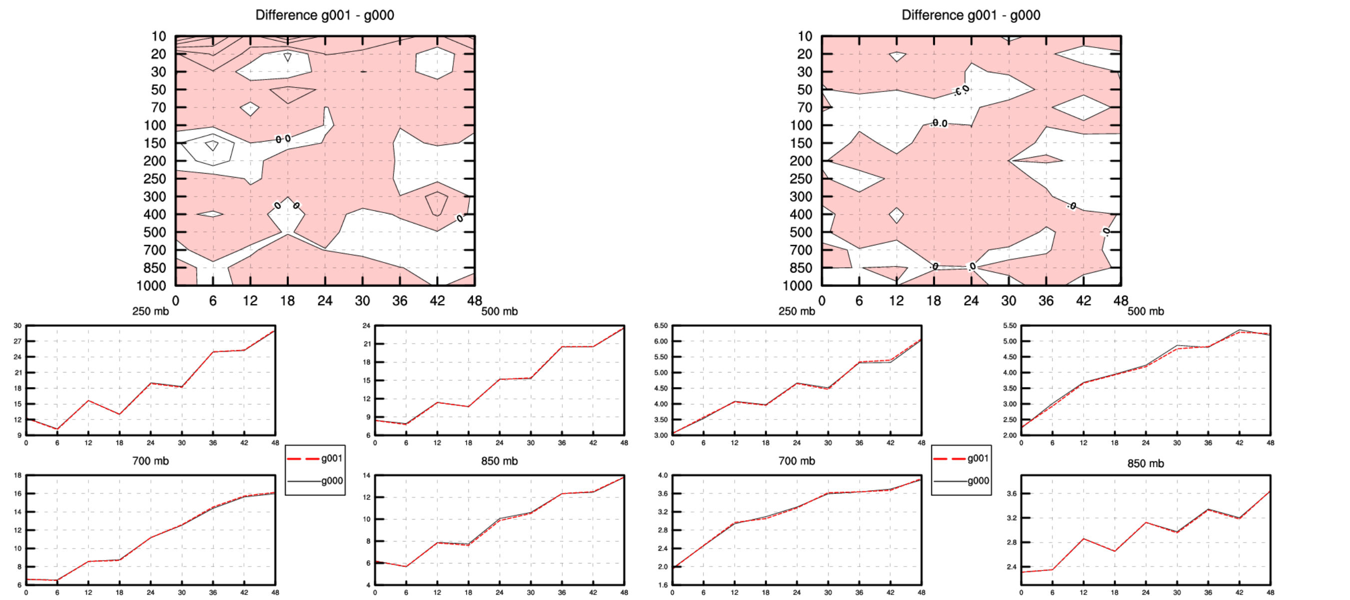


Fig. 8: the same as previous figure, but ϕ (left) and wind speed (right).

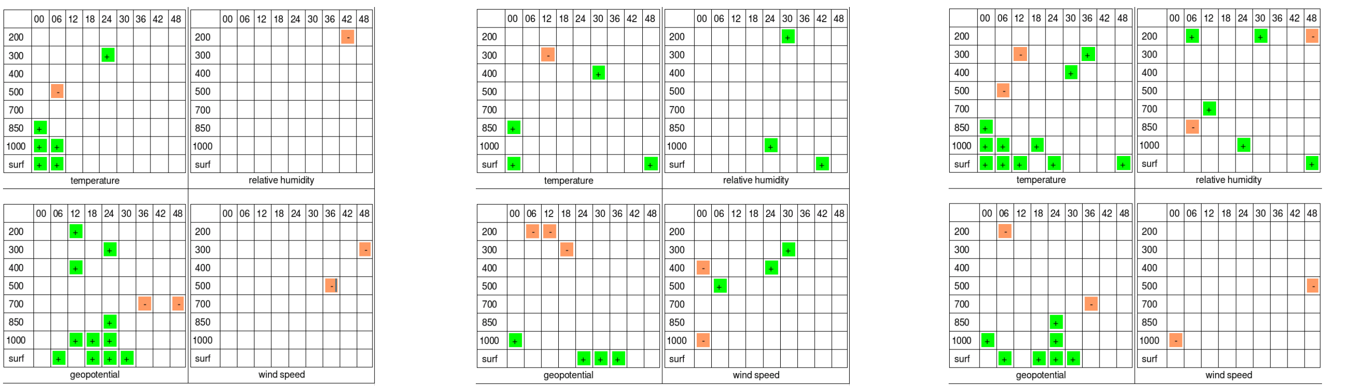


Fig. 9. List of parameters and forecast ranges where 3h 3DVAR (G001) performs better (in green)/worse (in red) than 6h 3DVAR (G000) in terms of RMSE scores against observation with significance 90% two side confidence interval significance test for 00 UTC productions (left), 12UTC productions (middle) and the both 00 and 12 UTC (right).

4 Impact of more frequent 3D-FGAT cycling

More frequent cycling was evaluated for 3D-FGAT method as well and one should remind specificities coming from technical problems mentioned in Section 2. 3h 3D-FGAT experiment is almost the same as 6h one, specifics are only LBCs at 03, 09, 15 and 21 UTC and 3 hour observation window. More frequent cycling brought also one simplification for 3D-FGAT, where a guess creation could be skipped and an analysis was used as starting point of subsequent assimilation.

4.1 Observation overview

Similarly to 3h 3DVAR experiment there was expected double total amount of SYNOP, AMDAR, SATOB and wind-profiler observations due to more frequent cycling and the same number of TEMP and SATEM data. Total observation statistics confirmed double increase of above mentioned observation types, but there is unexplained TEMP and SATEM observation decrease. Similarly to more frequent 3DVAR cycling, standard deviation were smaller for 3h 3D-FGAT, which means better fit to observations.

	Var	Total	Total*	Active	Active*	O-G Mean		O-A Mean		O-G STD		O-A STD	
		G002	G003	G002	G003	G002	G003	G002	G003	G002	G003	G002	G003
SYNOP	Geo	43054	191.9	42317	193.2	11.25	10.74	3.01	2.51	70.07	62.38	40.71	37.80
AIREP	T	226134	192.7	177590	193.9	0.18	0.14	0.09	0.06	1.20	1.12	0.78	0.76
	U	226134	192.7	177663	193.9	-0.05	-0.07	-0.01	-0.01	2.94	2.78	1.77	1.74
	V	226134	192.7	177663	193.9	0.09	0.07	0.02	0.01	3.00	2.81	1.77	1.74
GEOWIND	U	92361	203.1	12183	211.0	-0.86	-0.63	-0.26	-0.20	3.05	2.71	1.47	1.38
	V	92361	203.1	12183	211.0	0.27	0.03	0.03	-0.01	2.83	2.63	1.44	1.37
TEMP	Geo	27236	97.8	25391	97.7	-0.83	-1.60	-1.54	-1.67	14.37	14.50	11.94	11.44
	T	68948	97.8	67079	97.8	-0.08	-0.09	0.01	0.00	1.41	1.37	0.94	0.92
	U	61476	97.7	59949	97.7	0.02	0.04	0.05	0.05	3.29	3.26	2.12	2.11
	V	61476	97.7	59949	97.7	-0.03	-0.06	-0.03	-0.03	3.33	3.29	2.04	2.03
	Q	61599	97.8	40484	97.8	-0.00	0.02	-0.00	-0.00	0.52	0.54	0.25	0.25
WProf	U	192314	206.5	7305	199.4	0.45	0.28	-2.07	-1.24	2.39	2.19	0.04	1.01
	V	150813	192.3	5478	180.5	0.15	0.16	-0.34	-0.04	2.68	2.28	0.01	0.21
N15 AMSU-A	5	94568	79.1	4045	77.7	0.01	0.01	0.01	0.02	0.22	0.21	0.16	0.15
	7	94840	79.2	4543	77.6	-0.08	-0.08	-0.06	-0.06	0.17	0.16	0.16	0.15
	8	94572	79.1	16420	76.9	0.02	0.02	0.03	0.02	0.17	0.16	0.14	0.14
	9	94570	79.1	16414	77.0	-0.03	-0.02	0.01	0.02	0.24	0.23	0.17	0.16
	10	94568	79.1	16215	77.1	-0.06	-0.07	-0.03	-0.03	0.37	0.33	0.21	0.20
	12	94260	79.1	14713	75.8	0.11	0.05	0.09	0.07	1.31	1.27	0.65	0.60
N15 AMSU-B	3	856168	79.2	8568	77.2	0.38	0.14	-0.33	-0.35	3.31	3.23	2.04	1.88
	4	856090	79.2	7276	78.2	2.36	2.26	1.39	1.16	3.92	3.81	2.34	2.07
	5	856218	79.2	5141	77.4	-0.08	-0.21	-0.31	-0.48	2.54	2.49	1.56	1.47
N16 AMSU-A	8	122466	85.5	18898	82.8	-0.06	-0.05	-0.03	-0.01	0.42	0.42	0.34	0.33
	9	139750	86.6	22844	84.3	-0.04	-0.03	-0.01	0.00	0.33	0.32	0.22	0.22
	10	129778	85.7	19904	84.9	0.12	0.10	-0.05	-0.04	0.45	0.43	0.25	0.25
	11	140492	86.6	21252	86.3	0.38	0.34	0.23	0.25	0.75	0.70	0.43	0.41
	12	134052	86.1	19729	80.9	-0.81	-0.89	-0.71	-0.65	1.25	1.27	0.86	0.87
N16 AMSU-B	3	1294820	86.8	11172	84.3	0.23	0.07	0.08	0.09	3.98	3.95	2.38	2.23
	4	1294824	86.8	10794	85.0	-0.29	-0.36	-0.21	-0.22	3.10	3.00	2.02	1.93
	5	1294804	86.8	6272	87.6	-0.17	-0.29	-0.05	-0.09	3.28	3.27	2.34	2.25
N17 AMSU-B	3	1090605	75.7	10505	74.6	0.21	-0.06	0.05	0.10	2.43	2.56	1.22	0.84
	4	1090599	75.7	10247	74.8	-0.25	-0.52	-0.16	-0.03	2.22	2.30	1.18	0.82
	5	1090608	75.7	6769	73.9	-0.30	-0.40	-0.11	-0.04	1.98	2.03	1.22	1.01
N18 AMSU-A	5	118454	95.5	4603	94.7	0.07	0.08	0.08	0.07	0.26	0.25	0.19	0.19
	6	118454	95.5	4860	95.0	-0.10	-0.10	-0.06	-0.06	0.16	0.16	0.14	0.13
	7	118454	95.5	5249	95.0	-0.10	-0.10	-0.06	-0.07	0.20	0.20	0.17	0.16
	8	118454	95.5	21691	96.6	0.02	0.02	0.03	0.01	0.23	0.22	0.18	0.17
	9	118454	95.5	21687	96.6	-0.03	-0.01	-0.00	-0.01	0.26	0.27	0.16	0.15
	10	118454	95.5	20943	96.8	-0.01	0.00	0.01	-0.00	0.41	0.41	0.21	0.19
	11	118454	95.5	20772	96.9	0.03	0.01	0.00	-0.01	0.69	0.68	0.38	0.34
	12	118454	95.5	19945	94.5	0.11	0.04	0.01	-0.05	1.30	1.35	0.78	0.78
N18 AMSU-B	3	1083033	95.4	11610	96.1	0.24	0.06	0.09	0.07	2.42	2.37	0.96	0.69
	4	1083018	95.4	11180	96.0	-0.30	-0.34	-0.10	-0.02	2.21	2.11	0.96	0.70
	5	1083027	95.4	6729	95.8	-0.42	-0.42	-0.15	-0.12	2.08	2.00	1.05	0.89

Table 3: Observation summary for **G003** (20090114 00 UTC - 20090131 18 UTC) of all analyses. * relative difference with respect to **G002**.

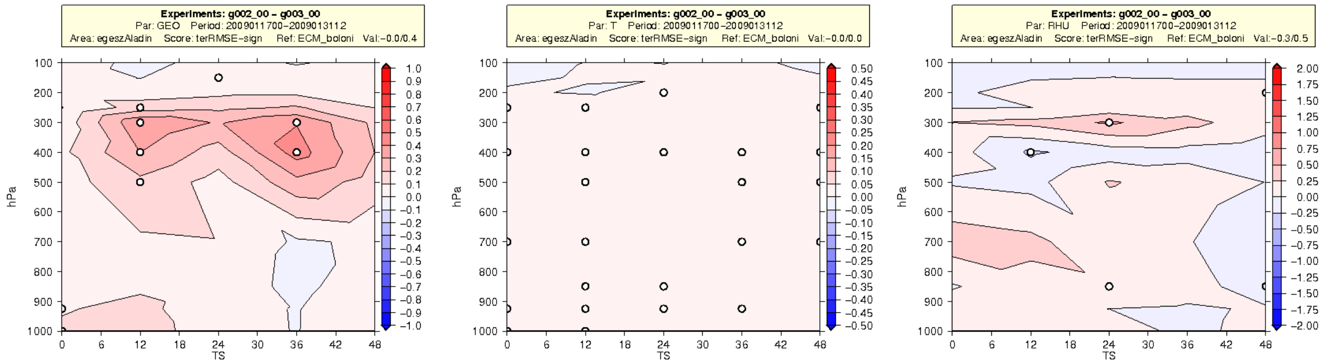
4.2 Comparison against analyses

Both 00 and 12 UTC forecasts were evaluated with respect to ECMWF analysis and on following figures RMSE differences of geopotential, temperature, relative humidity and

wind components are displayed. White circles show that the difference is better/worse with significance 90% two-side confidence interval.

4.2.1 Comparison against ECMWF analyses

There can be found mainly positive impact for 00UTC forecasts, while rather neutral or even negative impact for 12 UTC runs (especially above 850 hPa). The reason is unexplained so far, the observation statistics could be more elaborated to get any hint.



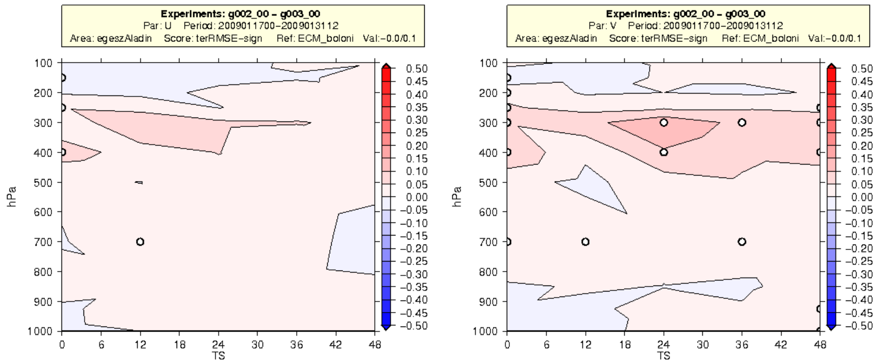
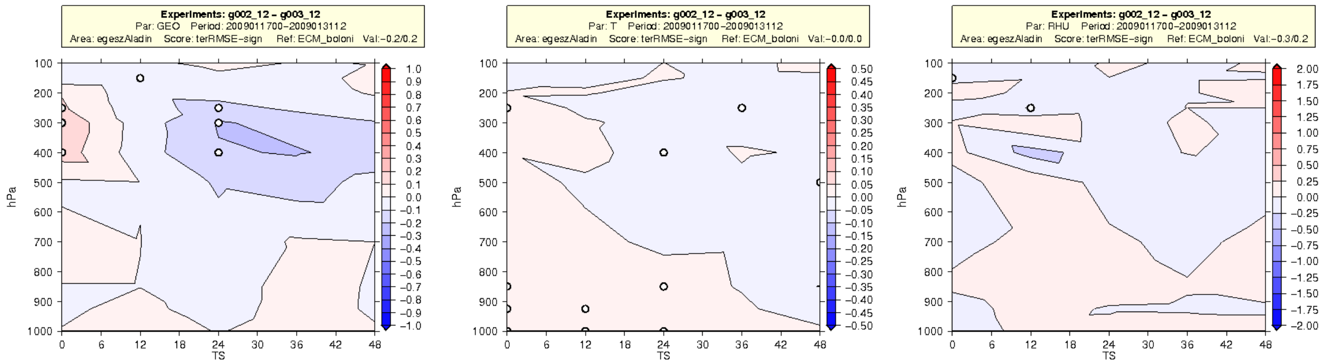


Fig. 10: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3D-FGAT (G002) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.



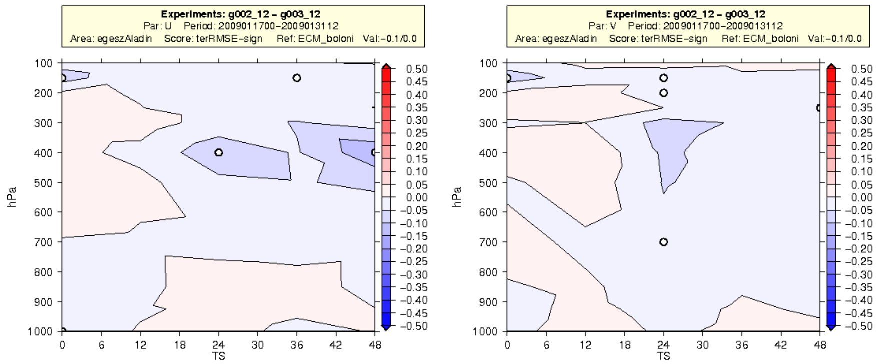
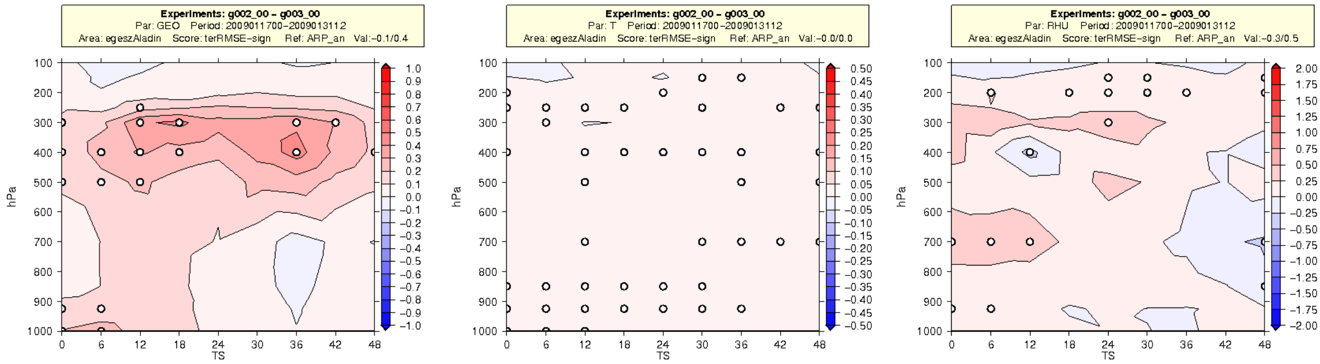


Fig. 11: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3D-FGAT (G002) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

4.2.2 Comparison against ARPEGE analyses

Verification with respect to ARPEGE analysis showed qualitatively the same results.



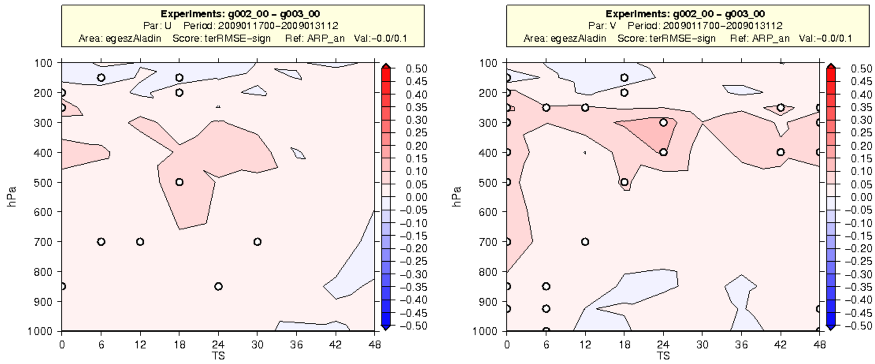
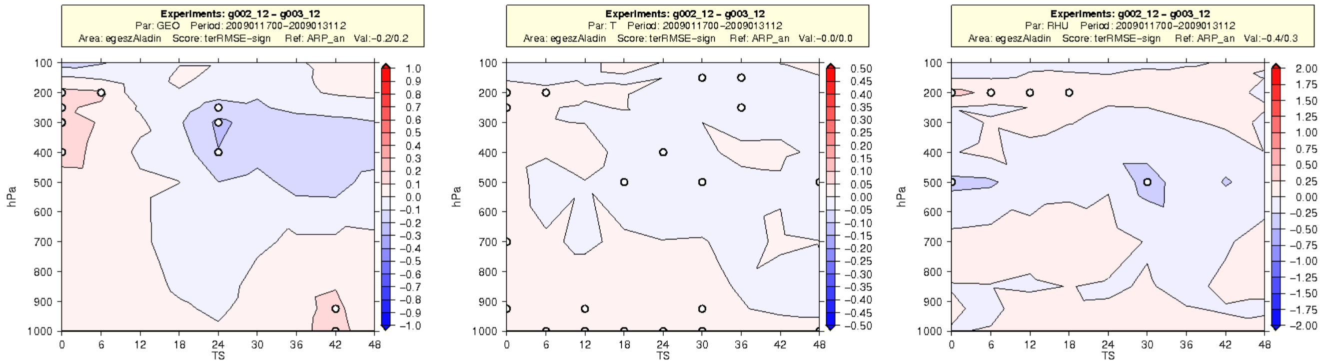


Fig. 12: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3D-FGAT (G002) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.



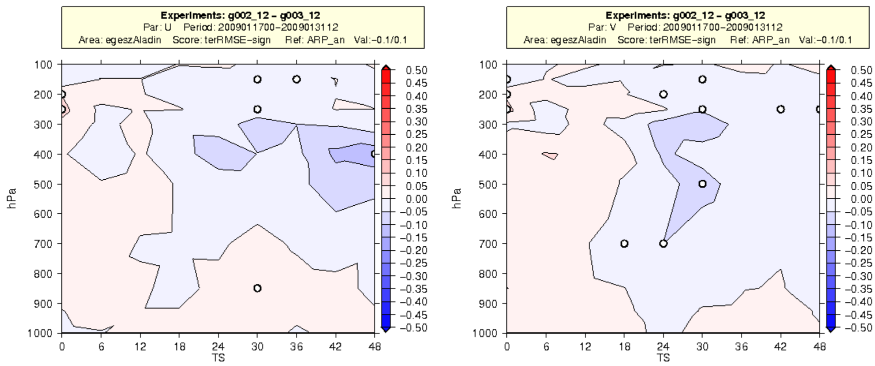


Fig. 13: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3D-FGAT (G002) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.

4.3 Comparison against observation

Forecasts were evaluated with respect to SYNOP and TEMP observation for testing period of 15 days in January 2009 and on following figures RMSE differences of geopotential, temperature, relative humidity and wind speed are displayed. There were found again very small differences. And only the results of significance test showed encouraging positive impact mainly in lower troposphere and for surface parameters.

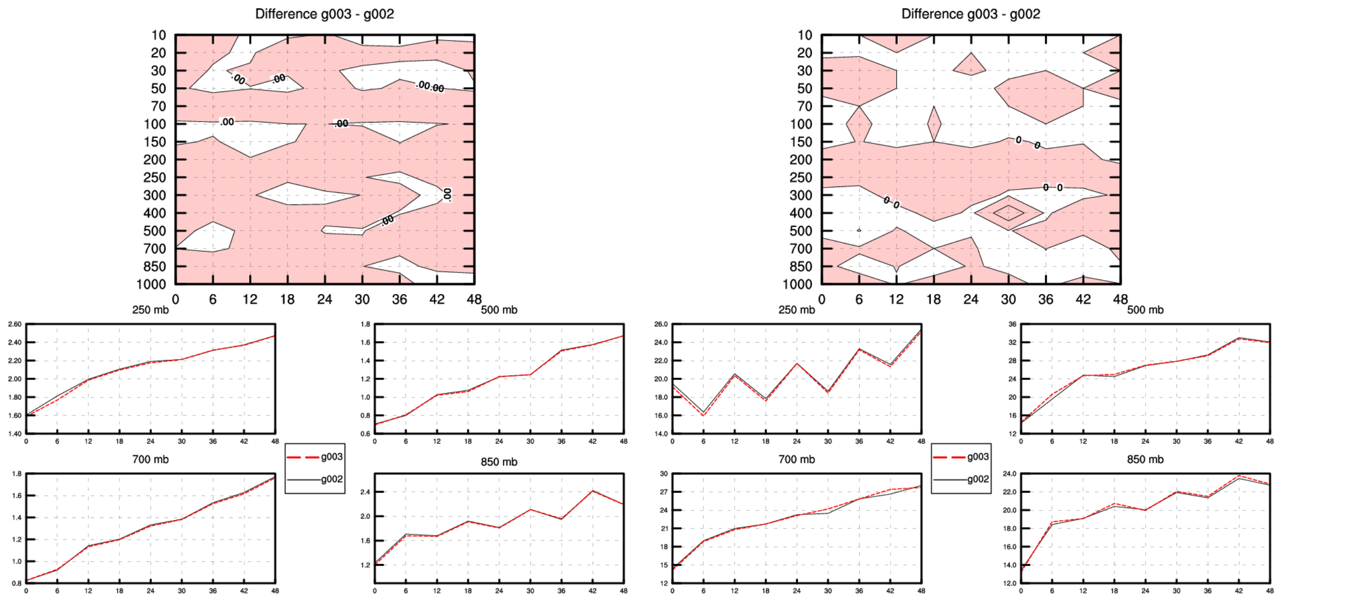


Fig. 14: RMSE of T (left) and RH (right),red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3D-FGAT (G002) against observation.

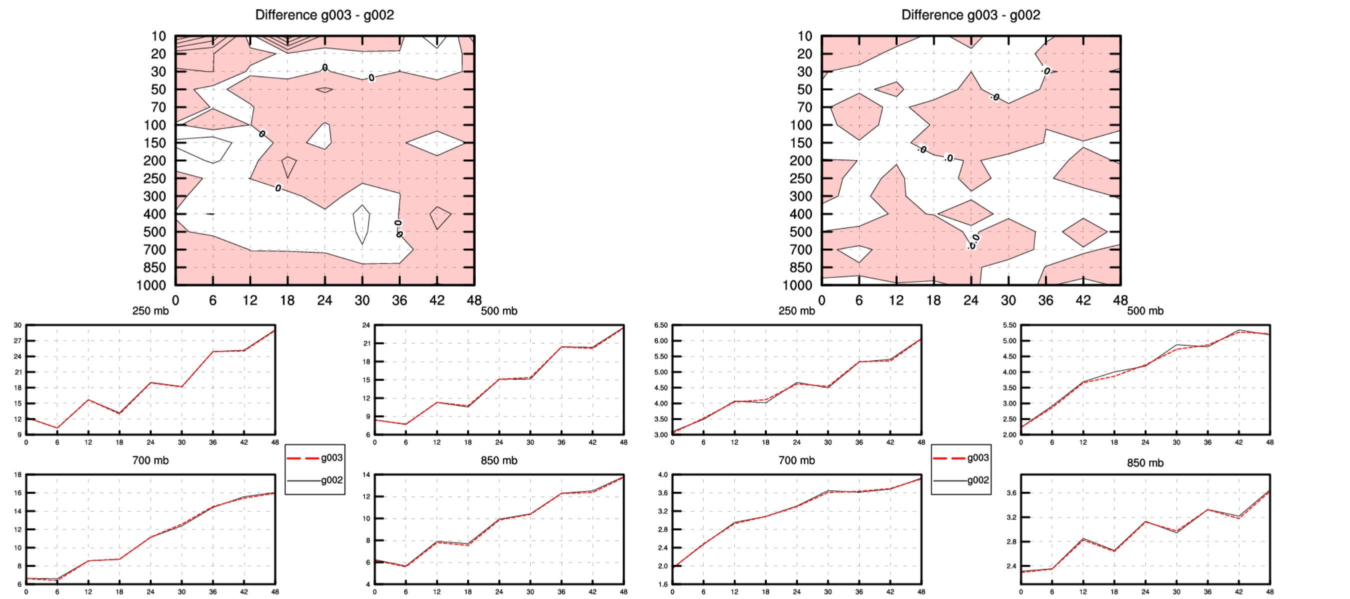


Fig. 15: the same as previous figure, but ϕ (left) and wind speed (right).

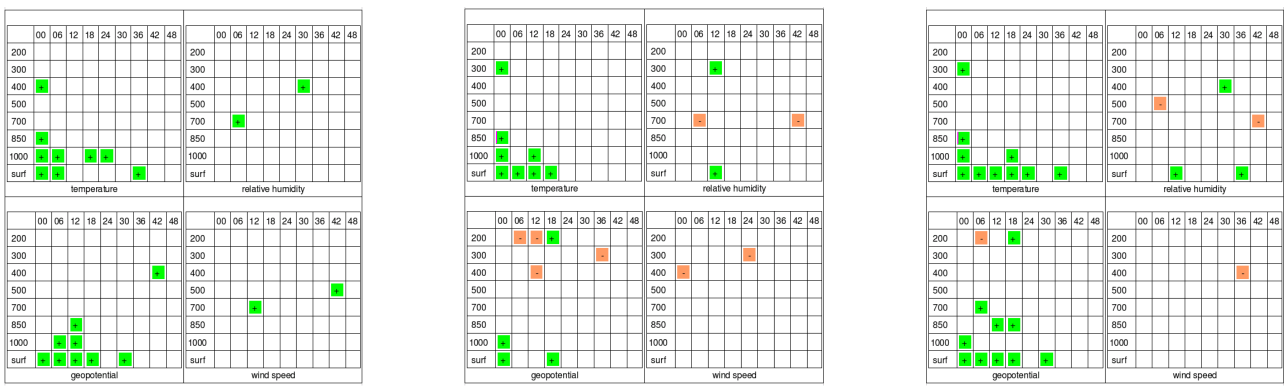


Fig. 16. List of parameters and forecast ranges where 3h 3D-FGAT (G003) performs better (in green)/worse (in red) than 6h 3D-FGAT (G002) in terms of RMSE scores against observation with significance 90% two side confidence interval significance test for 00 UTC productions (top-left), 12UTC productions (top-right) and the both 00 and 12 UTC (bottom).

5 Impact of 6h 3D-FGAT

As noted by Kertész (2006) the 3D-FGAT is thought to be more advanced than 3DVAR due to its more precise observation handling in case there are available observation at different times than the analysis time. In performed experiments this could be the case for AMDAR and SATEM observations. In this section 6h 3D-FGAT experiment was compared with 6h 3DVAR without AMDAR filter, the experiment G005.

5.1 Observation overview

As mentioned before observation were provided by OPLACE in hourly time-slots. Both experiments used the same observation data set. Note, that both experiments G002 and G005 were performed without AMDAR filter, thus the expectation is to have the same total number of data. Observation statistics are summarized in following Table 4. There were found small differences about 0.001% in total numbers of data, for the moment the reason is unexplained. Concerning active data the 3D-FGAT has about 0.4% more aircraft data and about 10-70% more radiance. Thus we can expect in this comparison an impact of satellite data mainly. O-A statistics were not analyzed because their meaning is questionable as analysis increments was shifted to the middle of the observation window. Standard deviation of O-G are mainly a little bit smaller for 3D-FGAT and mean of O-G has no clear signal (sometimes smaller/bigger for 3D-FGAT).

	Var	Total	Total*	Active	Active*	O-G Mean		O-A Mean		O-G STD		O-A STD	
		G005	G002	G005	G002	G005	G002	G005	G002	G005	G002	G005	G002
SYNOP	Geo	43054	100.0	42314	100.0	16.63	11.25	3.37	3.01	69.16	70.07	40.89	40.71
AIREP	T	226129	100.0	177004	100.3	0.15	0.18	0.08	0.09	1.22	1.20	0.81	0.78
	U	226129	100.0	177041	100.4	-0.03	-0.05	-0.00	-0.01	3.11	2.94	1.83	1.77
	V	226129	100.0	177041	100.4	0.04	0.09	0.02	0.02	3.29	3.00	1.92	1.77
GEOWIND	U	92358	100.0	12291	99.1	-0.47	-0.86	-0.17	-0.26	3.05	3.05	1.51	1.47
	V	92358	100.0	12291	99.1	-0.12	0.27	-0.10	0.03	2.86	2.83	1.49	1.44
TEMP	Geo	27236	100.0	25378	100.1	-2.08	-0.83	-1.63	-1.54	14.40	14.37	11.96	11.94
	T	68948	100.0	67088	100.0	-0.11	-0.08	0.01	0.01	1.40	1.41	0.93	0.94
	U	61476	100.0	59933	100.0	0.07	0.02	0.06	0.05	3.32	3.29	2.13	2.12
	V	61476	100.0	59933	100.0	-0.06	-0.03	-0.03	-0.03	3.38	3.33	2.05	2.04
	Q	61599	100.0	40418	100.2	0.00	-0.00	-0.00	-0.00	0.53	0.52	0.25	0.25
WProf	U	192314	100.0	6537	111.7	0.49	0.45	-1.92	-2.07	2.42	2.39	0.01	0.04
	V	150813	100.0	4710	116.3	0.19	0.15	-0.25	-0.34	2.49	2.68	0.06	0.01
N15 AMSU-A	5	94568	100.0	3471	116.5	0.00	0.01	0.01	0.01	0.26	0.22	0.17	0.16
	7	94840	100.0	3943	115.2	-0.08	-0.08	-0.07	-0.06	0.22	0.17	0.16	0.16
	8	94572	100.0	13968	117.6	0.02	0.02	0.02	0.03	0.28	0.17	0.15	0.14
	9	94570	100.0	13932	117.8	-0.04	-0.03	0.01	0.01	0.36	0.24	0.16	0.17
	10	94568	100.0	13514	120.0	-0.07	-0.06	-0.01	-0.03	0.43	0.37	0.19	0.21
	12	94260	100.0	12518	117.5	0.03	0.11	0.01	0.09	1.39	1.31	0.61	0.65
N15 AMSU-B	3	856168	100.0	6263	136.8	0.27	0.38	-0.32	-0.33	3.88	3.31	1.85	2.04
	4	856090	100.0	5284	137.7	2.03	2.36	0.95	1.39	4.16	3.92	1.94	2.34
	5	856218	100.0	3872	132.8	-0.11	-0.08	-0.54	-0.31	2.78	2.54	1.42	1.56
N16 AMSU-A	8	122466	100.0	12271	154.0	-0.03	-0.06	-0.01	-0.03	0.43	0.42	0.33	0.34
	9	139750	100.0	14659	155.8	0.01	-0.04	0.01	-0.01	0.39	0.33	0.21	0.22
	10	129778	100.0	12485	159.4	0.13	0.12	-0.06	-0.05	0.46	0.45	0.24	0.25
	11	140492	100.0	13204	161.0	0.40	0.38	0.29	0.23	0.69	0.75	0.37	0.43
	12	134052	100.0	12396	159.2	-0.94	-0.81	-0.72	-0.71	1.27	1.25	0.85	0.86
N16 AMSU-B	3	1294820	100.0	6894	162.1	0.28	0.23	0.10	0.08	4.32	3.98	2.19	2.38
	4	1294824	100.0	6709	160.9	-0.13	-0.29	-0.07	-0.21	3.41	3.10	1.86	2.02
	5	1294804	100.0	4006	156.6	0.00	-0.17	-0.00	-0.05	3.38	3.28	2.19	2.34
N17 AMSU-B	3	1090605	100.0	7013	149.8	-0.08	0.21	0.12	0.05	3.56	2.43	0.98	1.22
	4	1090599	100.0	6767	151.4	-0.56	-0.25	-0.06	-0.16	3.01	2.22	0.91	1.18
	5	1090608	100.0	4022	168.3	-0.43	-0.30	-0.06	-0.11	2.39	1.98	1.06	1.22
N18 AMSU-A	5	118454	100.0	4684	98.3	0.01	0.07	0.06	0.08	0.28	0.26	0.20	0.19
	6	118454	100.0	4914	98.9	-0.14	-0.10	-0.07	-0.06	0.18	0.16	0.14	0.14
	7	118454	100.0	5327	98.5	-0.13	-0.10	-0.07	-0.06	0.23	0.20	0.17	0.17
	8	118454	100.0	20425	106.2	-0.01	0.02	0.01	0.03	0.27	0.23	0.19	0.18
	9	118454	100.0	20405	106.3	-0.05	-0.03	-0.02	-0.00	0.32	0.26	0.16	0.16
	10	118454	100.0	19405	107.9	-0.02	-0.01	-0.01	0.01	0.44	0.41	0.19	0.21
	11	118454	100.0	19204	108.2	0.01	0.03	-0.01	0.00	0.73	0.69	0.36	0.38
	12	118454	100.0	18890	105.6	0.07	0.11	-0.05	0.01	1.32	1.30	0.79	0.78
N18 AMSU-B	3	1083033	100.0	9059	128.2	-0.08	0.24	0.10	0.09	2.99	2.42	0.78	0.96
	4	1083018	100.0	8709	128.4	-0.52	-0.30	0.00	-0.10	2.66	2.21	0.79	0.96
	5	1083027	100.0	5093	132.1	-0.57	-0.42	-0.14	-0.15	2.33	2.08	0.96	1.05

Table 4: Observation Summary for 6h 3D-FGAT **G002** (20090114 00 UTC - 20090131 18 UTC) of all analyses. * relative difference with respect to **G005** (6h 3DVAR).

5.2 Comparison against analyses

Verification scores with respect to ECMWF analyses displayed on following figures exhibit very small differences, the improvements are mostly above 700 hPa level (especially around 400 hPa), while degradation is below especially for temperature, geopotential. Similar patterns in bigger extend are apparent in the verification scores with respect to ARPEGE analyses (see Fig 19 and Fig 20).

5.2.1 Comparison against ECMWF analyses

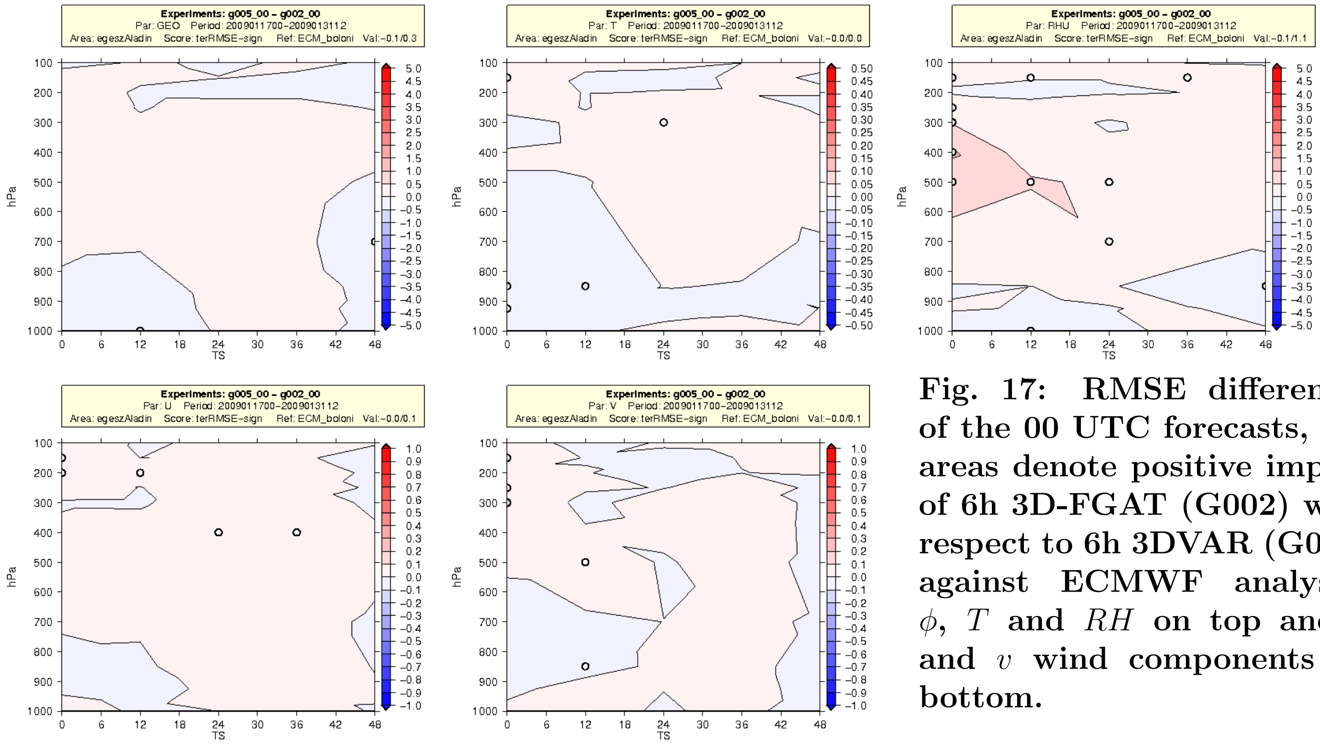


Fig. 17: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G005) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

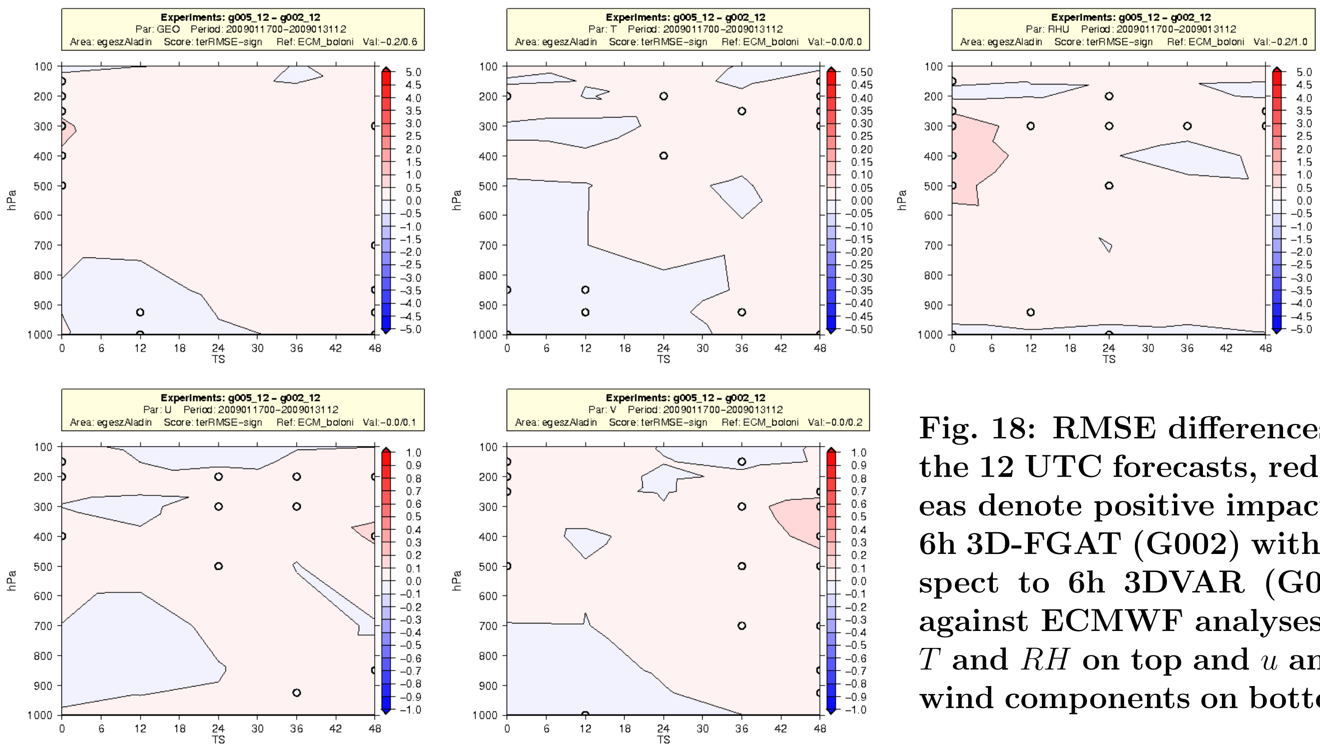
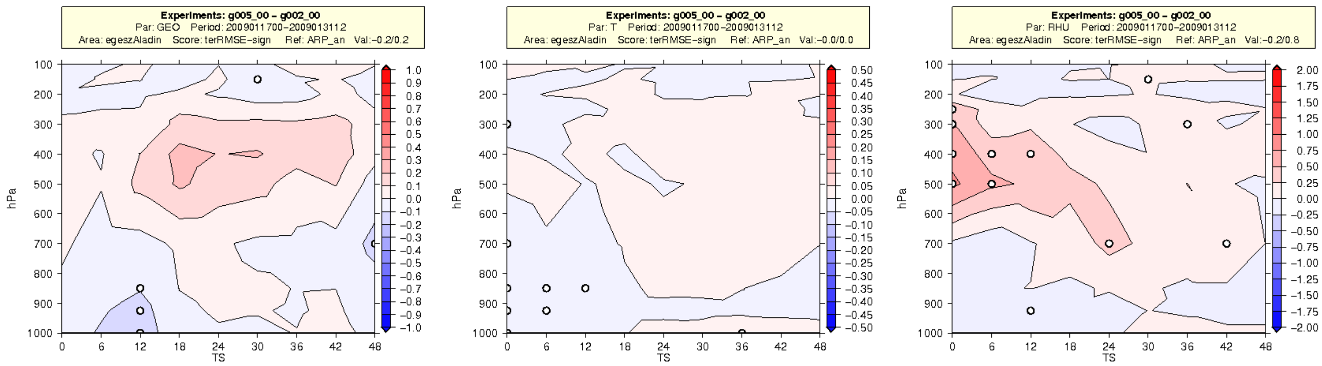


Fig. 18: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G005) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

5.2.2 Comparison against ARPEGE analyses



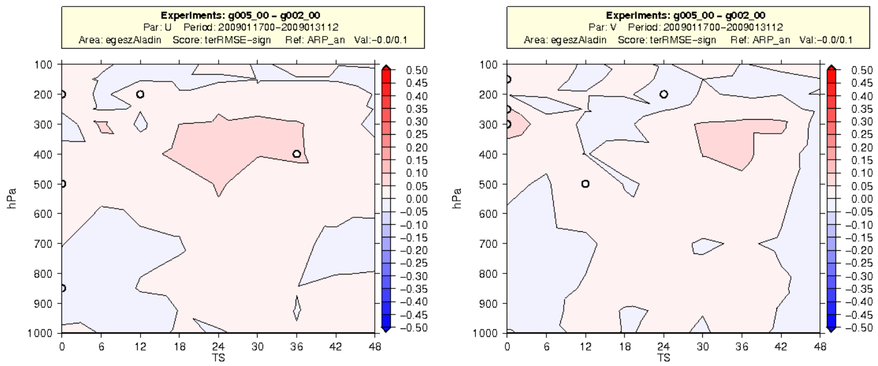
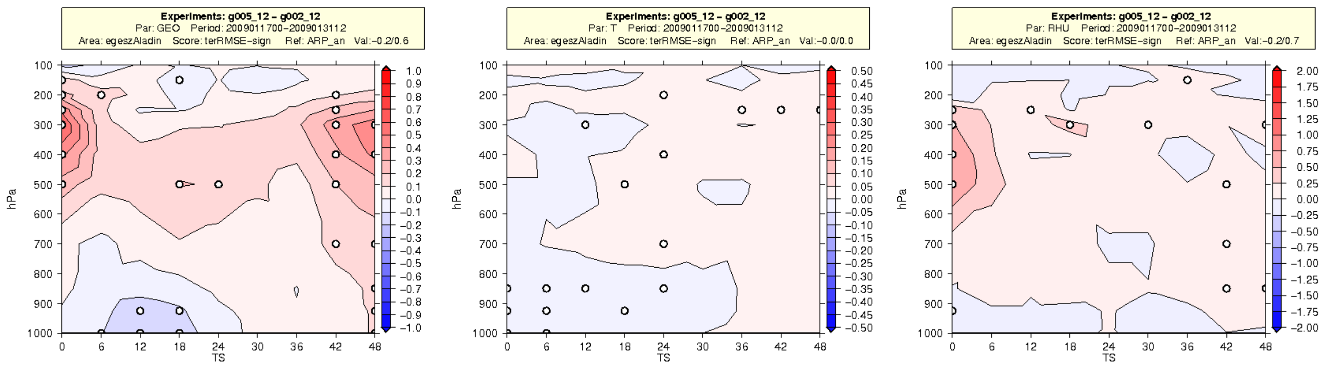


Fig. 19: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G005) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.



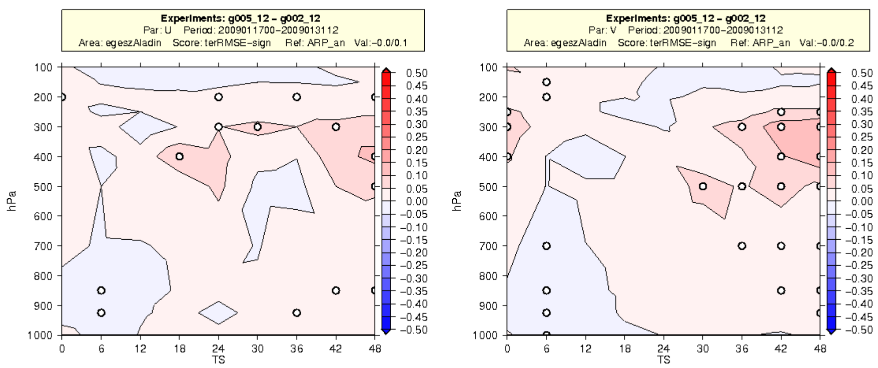


Fig. 20: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G005) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.

5.3 Comparison against observation

There are very small differences in RMSE scores, on following figure is an example of vertical cross-section of RMSE, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G005). The surface scores are almost identical (not shown). Rather mixed results of significance test are summarized on Fig 22.

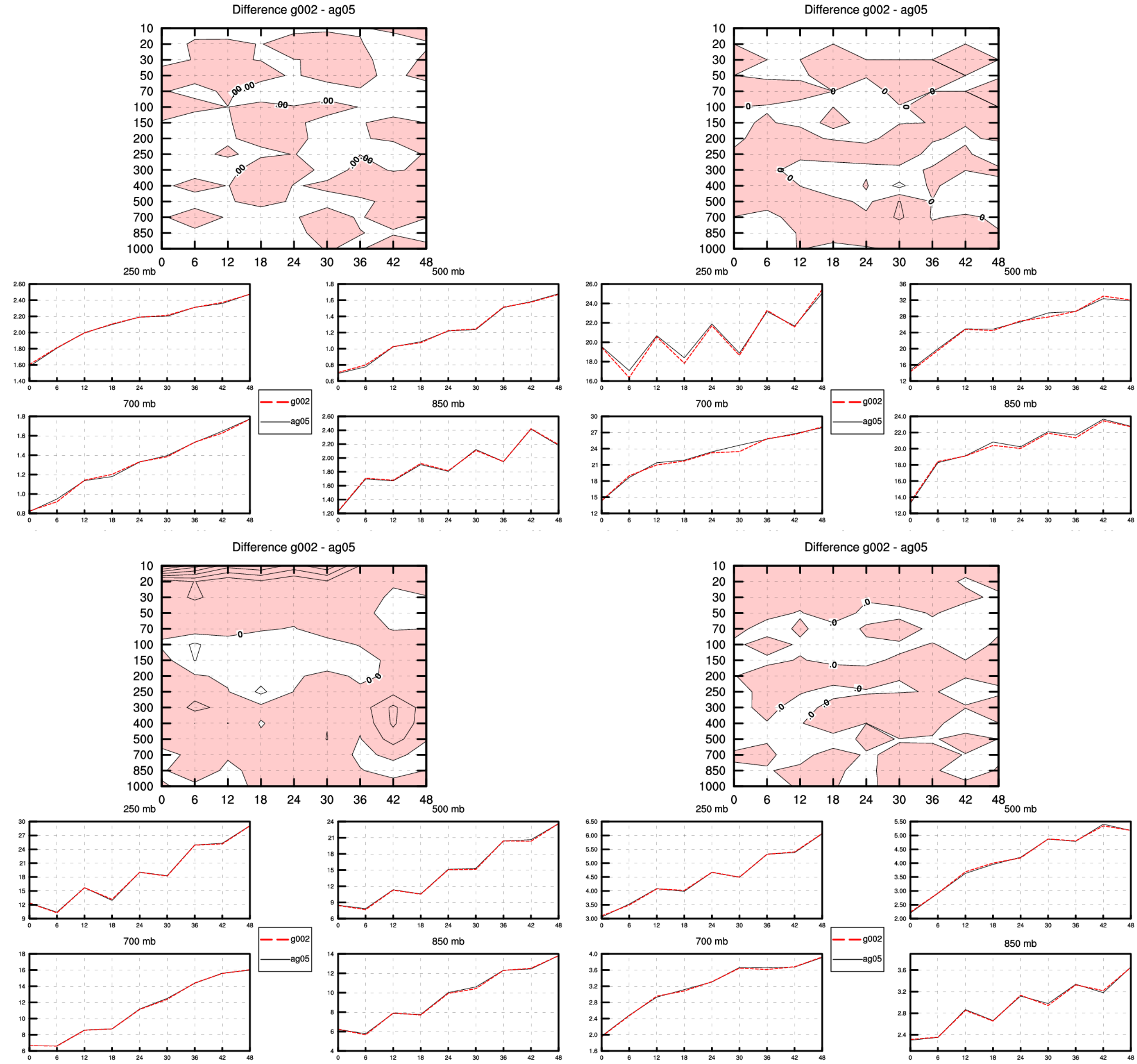


Fig. 21: RMSE of T and RH (top-left and right), ϕ and wind speed (bottom-left and right) red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G005) against TEMP.

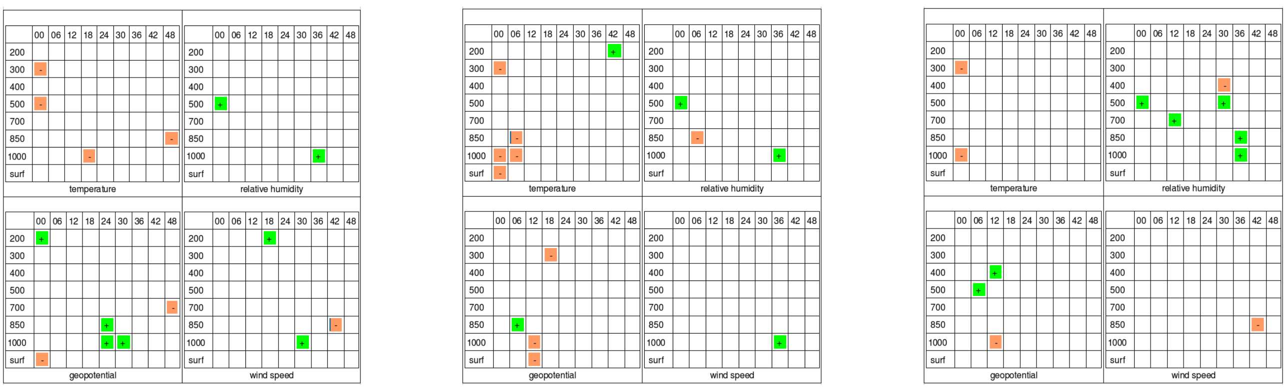


Fig. 22. List of parameters and forecast ranges where 6h 3D-FGAT (G002) performs better (in green)/worse (in red) than 6h 3DVAR (G005) in terms of RMSE scores against observation with significance 90% two side confidence interval significance test for 00 UTC productions (left), 12UTC productions (middle) and both 00 and 12 UTC (right).

6 Impact of 6h 3D-FGAT with aditional AMDAR data

In this section 6h 3D-FGAT experiment was compared with the reference experiment G000 designed as close as possible to current operational ALADIN/HU setting, which comprises an additional filtering of AMDAR data. The impact with respect to this reference can be seen as adding more AMDAR data.

6.1 Observation overview

Both experiments used the same observational data set, The difference was in treatment of AMDAR data only, experiment G002 was performed without AMDAR filter, thus the expectation is to have more AMDAR in FGAT experiment. Observation statistics are summarized in following Table 5. There were found small differences about 0.001% in total numbers of data, for the moment the reason is unexplained. The 3D-FGAT has almost double total number of AMDAR data and about 59% more active data and about 10-70% more of active radiance. Thus we can expect combined impact of satellite and aircraft data. O-G Mean statistics were mixed and standard deviation were mainly smaller for the 3D-FGAT experiment.

	Var	Total	Total*	Active	Active*	O-G Mean		O-A Mean		O-G STD		O-A STD	
		G000	G002	G000	G002	G000	G002	G000	G002	G000	G002	G000	G002
SYNOP	Geo	43054	100.0	42314	100.0	16.39	11.25	3.09	3.01	69.14	70.07	40.73	40.71
AIREP	T	115249	196.2	111389	159.4	0.16	0.18	0.10	0.09	1.20	1.20	0.78	0.78
	U	115249	196.2	111926	158.7	-0.02	-0.05	-0.00	-0.01	3.09	2.94	1.73	1.77
	V	115249	196.2	111926	158.7	0.07	0.09	0.03	0.02	3.23	3.00	1.76	1.77
GEOWIND	U	92359	100.0	12293	99.1	-0.48	-0.86	-0.16	-0.26	3.08	3.05	1.49	1.47
	V	92359	100.0	12293	99.1	-0.11	0.27	-0.09	0.03	2.84	2.83	1.46	1.44
TEMP	Geo	27236	100.0	25398	100.0	-1.99	-0.83	-1.42	-1.54	14.45	14.37	11.91	11.94
	T	68948	100.0	67080	100.0	-0.10	-0.08	0.01	0.01	1.40	1.41	0.93	0.94
	U	61476	100.0	59939	100.0	0.08	0.02	0.06	0.05	3.34	3.29	2.12	2.12
	V	61476	100.0	59939	100.0	-0.06	-0.03	-0.03	-0.03	3.37	3.33	2.03	2.04
	Q	61599	100.0	40448	100.1	-0.00	-0.00	-0.00	-0.00	0.53	0.52	0.25	0.25
WProf	U	98073	196.1	626	1166.9	0.93	0.45	-0.65	-2.07	2.17	2.39	0.92	0.04
	V	79407	189.9	466	1175.5	0.16	0.15	-0.30	-0.34	2.72	2.68	0.12	0.01
N15 AMSU-A	5	94568	100.0	3480	116.2	-0.00	0.01	0.01	0.01	0.26	0.22	0.17	0.16
	7	94840	100.0	3950	115.0	-0.08	-0.08	-0.07	-0.06	0.22	0.17	0.16	0.16
	8	94572	100.0	13973	117.5	0.01	0.02	0.02	0.03	0.28	0.17	0.15	0.14
	9	94570	100.0	13942	117.7	-0.04	-0.03	0.00	0.01	0.36	0.24	0.16	0.17
	10	94568	100.0	13534	119.8	-0.07	-0.06	-0.01	-0.03	0.43	0.37	0.19	0.21
	12	94260	100.0	12511	117.6	0.03	0.11	0.01	0.09	1.39	1.31	0.61	0.65
N15 AMSU-5	3	856168	100.0	6266	136.7	0.29	0.38	-0.32	-0.33	3.91	3.31	1.86	2.04
	4	856090	100.0	5281	137.8	2.04	2.36	0.96	1.39	4.17	3.92	1.95	2.34
	5	856218	100.0	3870	132.8	-0.13	-0.08	-0.53	-0.31	2.78	2.54	1.42	1.56
N16 AMSU-A	8	122466	100.0	12268	154.0	-0.03	-0.06	-0.00	-0.03	0.43	0.42	0.33	0.34
	9	139750	100.0	14657	155.9	0.01	-0.04	0.01	-0.01	0.39	0.33	0.21	0.22
	10	129778	100.0	12484	159.4	0.13	0.12	-0.05	-0.05	0.46	0.45	0.24	0.25
	11	140492	100.0	13190	161.1	0.40	0.38	0.29	0.23	0.69	0.75	0.37	0.43
	12	134052	100.0	12400	159.1	-0.94	-0.81	-0.72	-0.71	1.27	1.25	0.85	0.86
N16 AMSU-B	3	1294820	100.0	6903	161.8	0.26	0.23	0.10	0.08	4.37	3.98	2.20	2.38
	4	1294824	100.0	6714	160.8	-0.14	-0.29	-0.07	-0.21	3.41	3.10	1.84	2.02
	5	1294804	100.0	4002	156.7	-0.01	-0.17	-0.02	-0.05	3.38	3.28	2.20	2.34
N17 AMSU-B	3	1090605	100.0	6997	150.1	-0.07	0.21	0.12	0.05	3.54	2.43	0.98	1.22
	4	1090599	100.0	6753	151.7	-0.56	-0.25	-0.05	-0.16	3.00	2.22	0.91	1.18
	5	1090608	100.0	4007	168.9	-0.45	-0.30	-0.08	-0.11	2.40	1.98	1.07	1.22
N18 AMSU-A	5	118454	100.0	4682	98.3	0.02	0.07	0.06	0.08	0.28	0.26	0.20	0.19
	6	118454	100.0	4909	99.0	-0.14	-0.10	-0.07	-0.06	0.18	0.16	0.14	0.14
	7	118454	100.0	5317	98.7	-0.13	-0.10	-0.07	-0.06	0.23	0.20	0.17	0.17
	8	118454	100.0	20434	106.2	-0.01	0.02	0.01	0.03	0.27	0.23	0.19	0.18
	9	118454	100.0	20414	106.2	-0.05	-0.03	-0.03	-0.00	0.32	0.26	0.16	0.16
	10	118454	100.0	19410	107.9	-0.02	-0.01	-0.01	0.01	0.44	0.41	0.19	0.21
	11	118454	100.0	19204	108.2	0.01	0.03	-0.01	0.00	0.72	0.69	0.36	0.38
	12	118454	100.0	18891	105.6	0.06	0.11	-0.05	0.01	1.32	1.30	0.78	0.78
N18 AMSU-B	3	1083033	100.0	9041	128.4	-0.10	0.24	0.10	0.09	2.98	2.42	0.78	0.96
	4	1083018	100.0	8708	128.4	-0.53	-0.30	-0.00	-0.10	2.66	2.21	0.79	0.96
	5	1083027	100.0	5092	132.1	-0.57	-0.42	-0.14	-0.15	2.32	2.08	0.97	1.05

Table 5: Observation Summary for 6h 3D-FGAT **G002** (20090114 00 UTC - 20090131 18 UTC) of all analyses. * relative difference with respect to **G000** (6h 3DVAR).

6.2 Comparison against analyses

RMSE difference are summarized on following figures. There are again the improvements mostly above 700 hPa level (specially around 400 hPa), while degradation is

below especially for geopotential and temperature. The impact is bigger than the comparison with respect to G005 (see previous Section 5) and is obviously coming from the additional AMDAR observations. Similar patterns are apparent in the verification scores with respect to ARPEGE analyses (see Fig 25 and Fig 26).

6.2.1 Comparison against ECMWF analyses

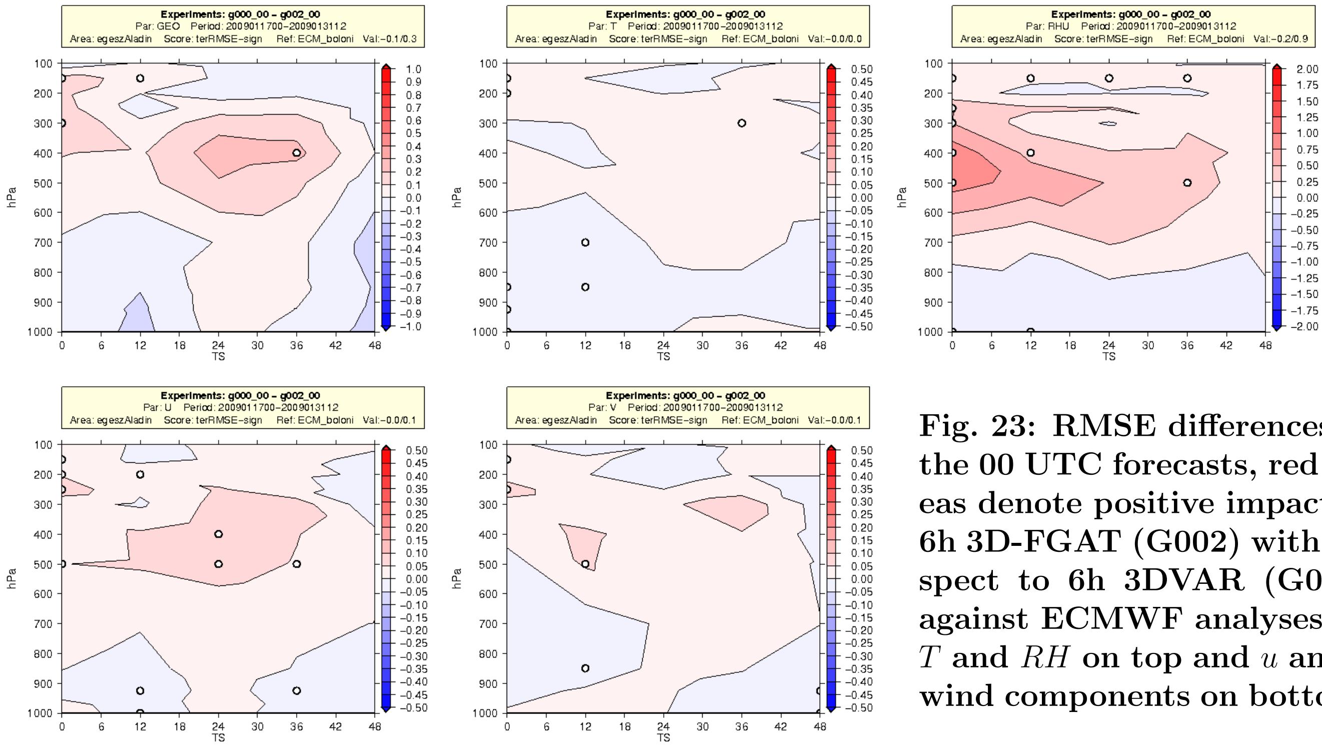


Fig. 23: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G000) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

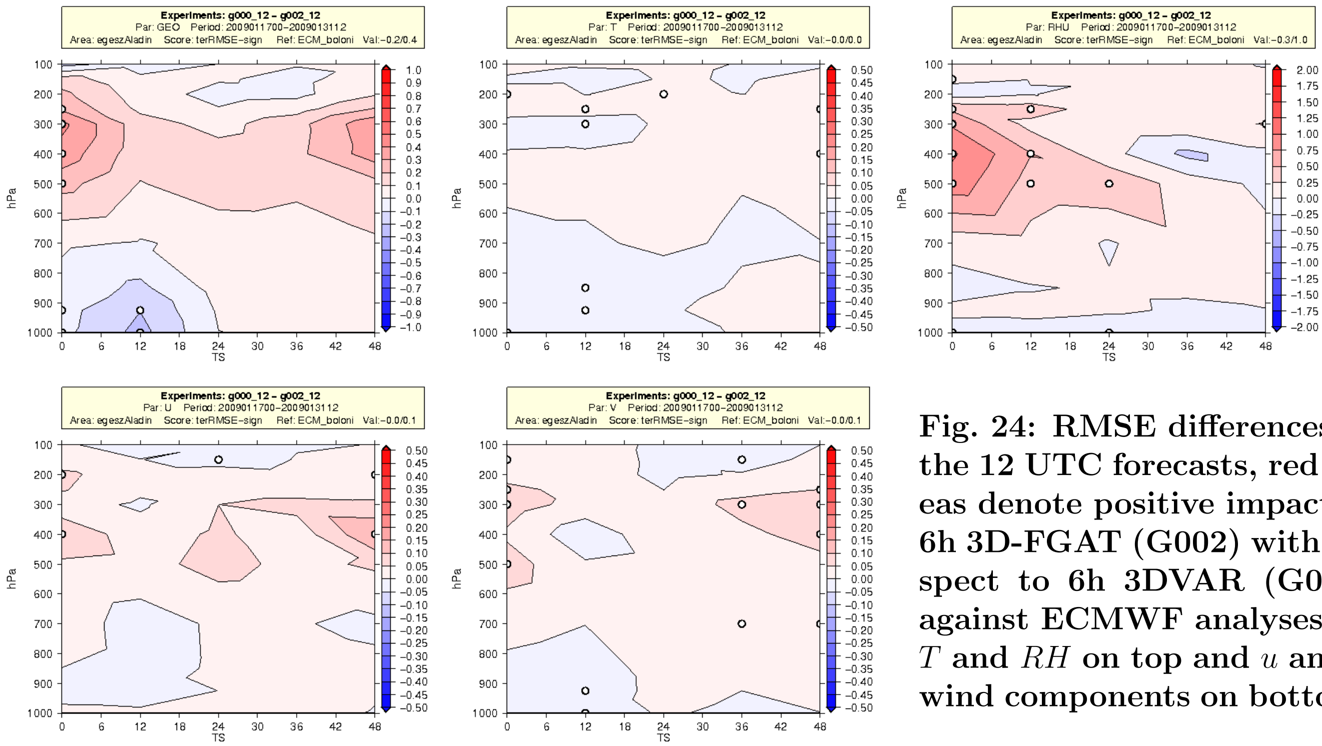
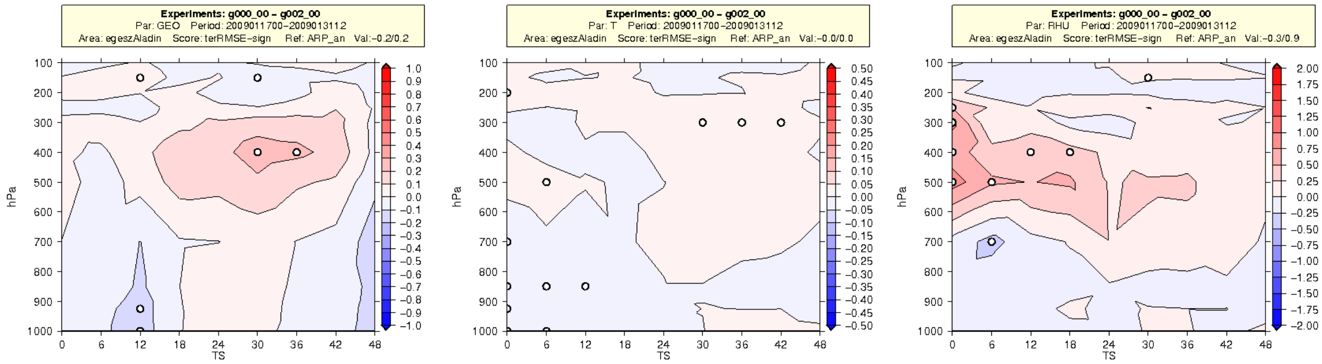


Fig. 24: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G000) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

6.2.2 Comparison against ARPEGE analyses



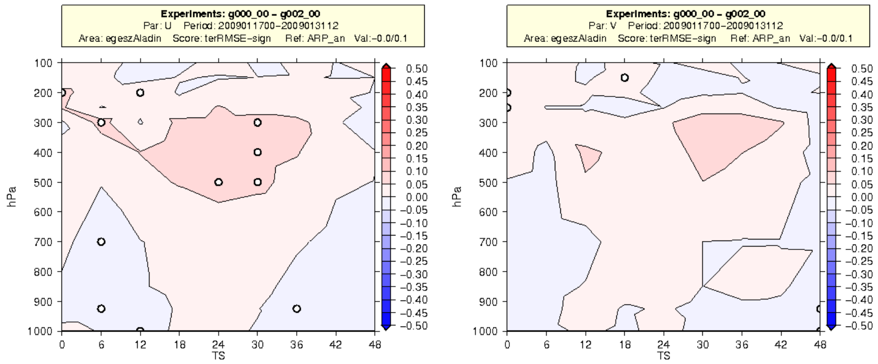
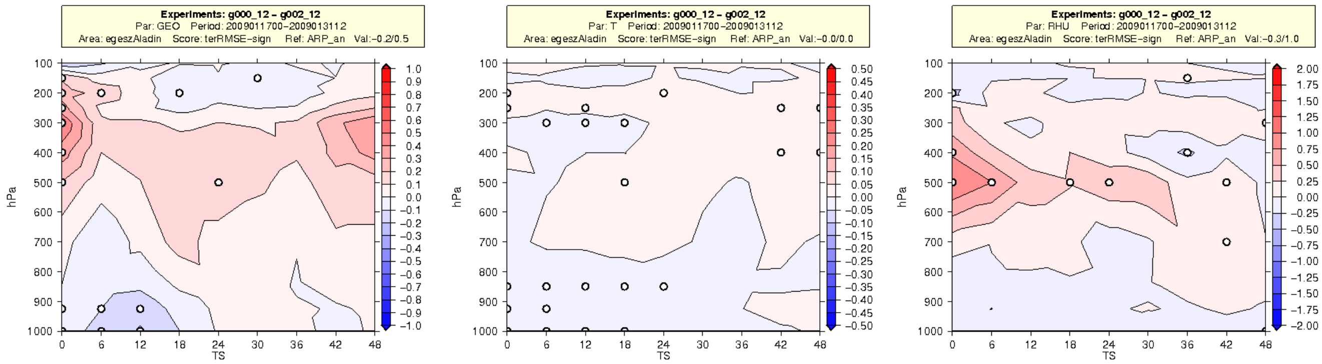


Fig. 25: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G000) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.



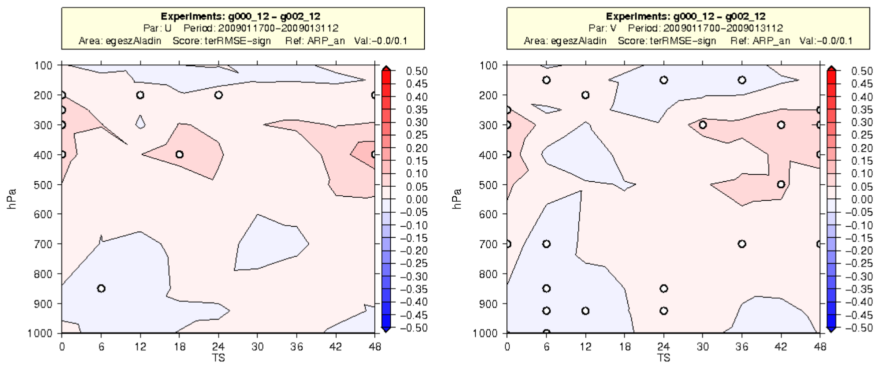


Fig. 26: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G000) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.

6.3 Comparison against observation

The statistics against observation show very small differences, noticeable is a little degradation around 150 hPa for geopotential. Complete summary of parameters and forecast ranges where 6h 3D-FGAT (G002) with aditional AMDAR data performs better (in green)/worse (in red) than 6h 3DVAR (G000) in terms of RMSE scores with significance 90% two side confidence interval significance test is summarized below on Fig. 28.

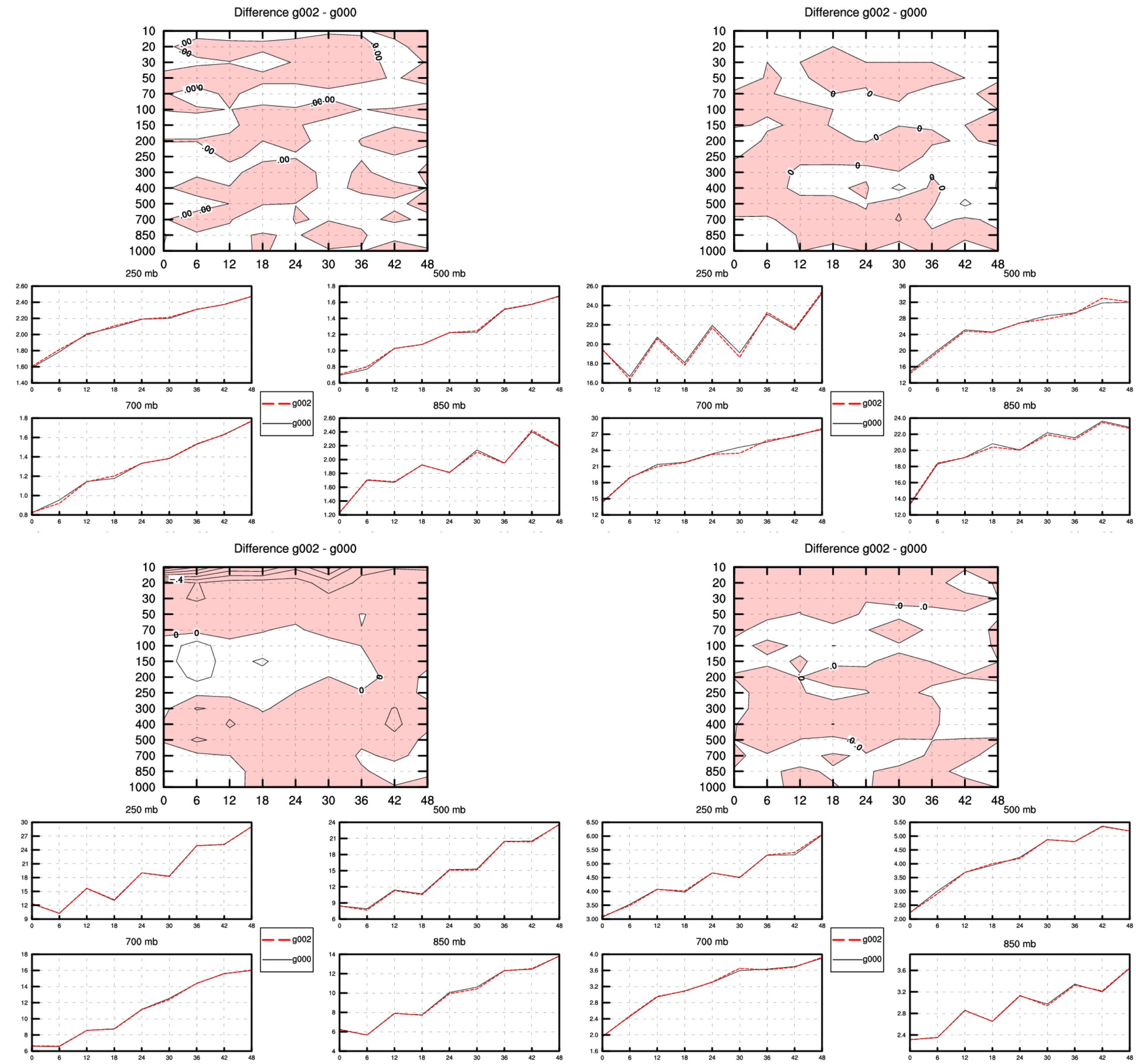


Fig. 27: RMSE of T and RH (top-left and right), ϕ and wind speed (bottom-left and right) red areas denote positive impact of 6h 3D-FGAT (G002) with respect to 6h 3DVAR (G000) against TEMP.

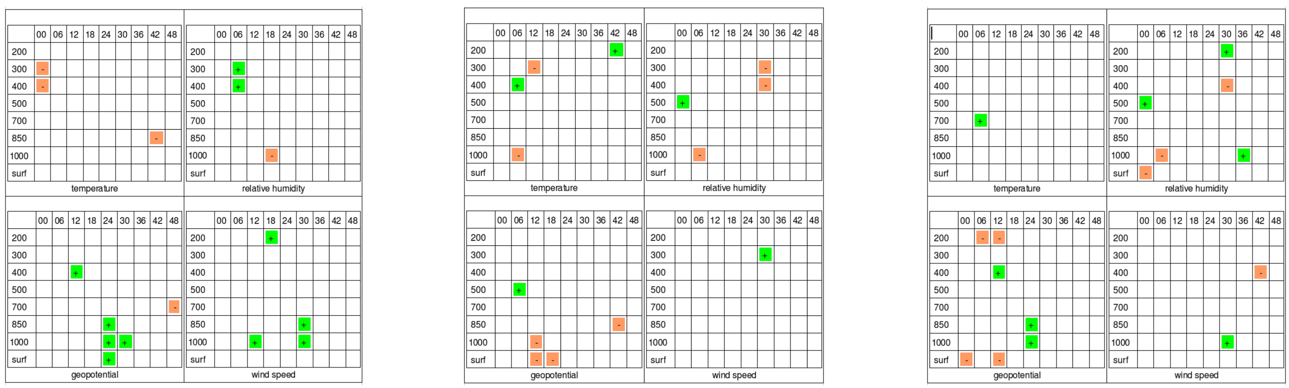


Fig. 28. List of parameters and forecast ranges where 6h 3D-FGAT (G002) performs better (in green)/worse (in red) than 6h 3DVAR (G000) in terms of RMSE scores against observation with significance 90% two side confidence interval significance test for 00 UTC productions (left), 12UTC productions (middle) and both 00 and 12 UTC (right).

7 Impact of 3h 3D-FGAT with aditional AMDAR data

In this section 3h 3D-FGAT experiment was compared with reference experiment G000 designed as close as possible to current operational ALADIN/HU setting, which comprises an additional filtering of AMDAR data. The comparison evaluated an impact of extra observation coming from more frequent cycling.

7.1 Observation overview

The 3h 3D-FGAT experiment G005 used SYNOP, TEMP, SATOB and wind-profiler data from the single time-slot valid at analysis time and AMDAR and SATEM from three middle times slots, which cover the 3 hour time-window. From more frequent cycling double amount of SYNOP, SATOB and wind-profiler data and the same number of TEMP and SATEM observation were expected. Next difference was in treatment of AMDAR data, G003 was performed without AMDAR filter, thus the expectation is to have more than double AMDAR in FGAT experiment. Observation statistics are summarized in Table 6. It confirmed expectation of almost double increase of SYNOP and SATOB and more than triple amount of AMDAR data. But there was found unexplained TEMP and SATEM decrease.

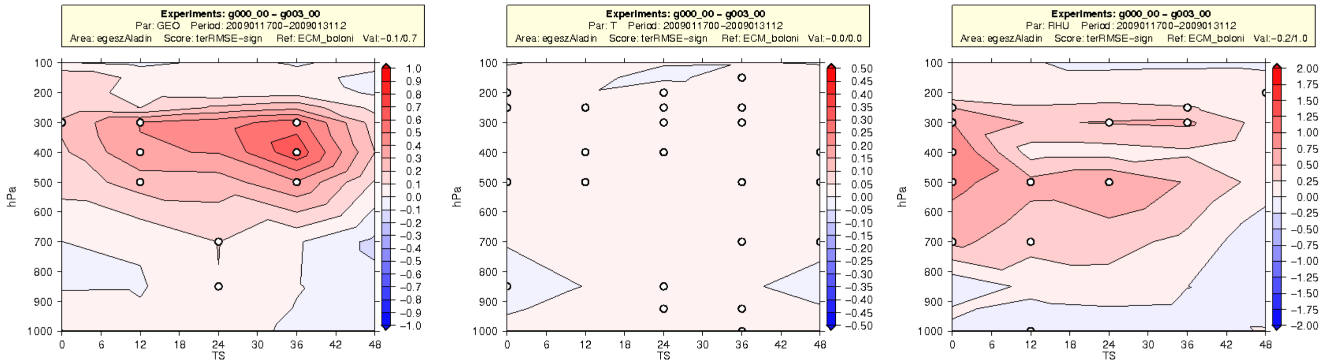
	Var	Total	Total*	Active	Active*	O-G Mean		O-A Mean		O-G STD		O-A STD	
		G000	G003	G000	G003	G000	G003	G000	G003	G000	G003	G000	G003
SYNOP	Geo	43054	191.9	42314	193.2	16.39	10.74	3.09	2.51	69.14	62.38	40.73	37.80
AIREP	T	115249	378.1	111389	309.1	0.16	0.14	0.10	0.06	1.20	1.12	0.78	0.76
	U	115249	378.1	111926	307.7	-0.02	-0.07	-0.00	-0.01	3.09	2.78	1.73	1.74
	V	115249	378.1	111926	307.7	0.07	0.07	0.03	0.01	3.23	2.81	1.76	1.74
GEOWIND	U	92359	203.1	12293	209.1	-0.48	-0.63	-0.16	-0.20	3.08	2.71	1.49	1.38
	V	92359	203.1	12293	209.1	-0.11	0.03	-0.09	-0.01	2.84	2.63	1.46	1.37
TEMP	Geo	27236	97.8	25398	97.6	-1.99	-1.60	-1.42	-1.67	14.45	14.50	11.91	11.44
	T	68948	97.8	67080	97.8	-0.10	-0.09	0.01	0.00	1.40	1.37	0.93	0.92
	U	61476	97.7	59939	97.8	0.08	0.04	0.06	0.05	3.34	3.26	2.12	2.11
	V	61476	97.7	59939	97.8	-0.06	-0.06	-0.03	-0.03	3.37	3.29	2.03	2.03
	Q	61599	97.8	40448	97.9	-0.00	0.02	-0.00	-0.00	0.53	0.54	0.25	0.25
WProf	U	98073	404.9	626	2327.2	0.93	0.28	-0.65	-1.24	2.17	2.19	0.92	1.01
	V	79407	365.2	466	2121.7	0.16	0.16	-0.30	-0.04	2.72	2.28	0.12	0.21
N15 AMSU-A	5	94568	79.1	3480	90.3	-0.00	0.01	0.01	0.02	0.26	0.21	0.17	0.15
	7	94840	79.2	3950	89.3	-0.08	-0.08	-0.07	-0.06	0.22	0.16	0.16	0.15
	8	94572	79.1	13973	90.4	0.01	0.02	0.02	0.02	0.28	0.16	0.15	0.14
	9	94570	79.1	13942	90.6	-0.04	-0.02	0.00	0.02	0.36	0.23	0.16	0.16
	10	94568	79.1	13534	92.4	-0.07	-0.07	-0.01	-0.03	0.43	0.33	0.19	0.20
	12	94260	79.1	12511	89.1	0.03	0.05	0.01	0.07	1.39	1.27	0.61	0.60
N15 AMSU-5	3	856168	79.2	6266	105.6	0.29	0.14	-0.32	-0.35	3.91	3.23	1.86	1.88
	4	856090	79.2	5281	107.7	2.04	2.26	0.96	1.16	4.17	3.81	1.95	2.07
	5	856218	79.2	3870	102.8	-0.13	-0.21	-0.53	-0.48	2.78	2.49	1.42	1.47
N16 AMSU-A	8	122466	85.5	12268	127.6	-0.03	-0.05	-0.00	-0.01	0.43	0.42	0.33	0.33
	9	139750	86.6	14657	131.4	0.01	-0.03	0.01	0.00	0.39	0.32	0.21	0.22
	10	129778	85.7	12484	135.3	0.13	0.10	-0.05	-0.04	0.46	0.43	0.24	0.25
	11	140492	86.6	13190	139.1	0.40	0.34	0.29	0.25	0.69	0.70	0.37	0.41
	12	134052	86.1	12400	128.8	-0.94	-0.89	-0.72	-0.65	1.27	1.27	0.85	0.87
N16 AMSU-B	3	1294820	86.8	6903	136.4	0.26	0.07	0.10	0.09	4.37	3.95	2.20	2.23
	4	1294824	86.8	6714	136.7	-0.14	-0.36	-0.07	-0.22	3.41	3.00	1.84	1.93
	5	1294804	86.8	4002	137.3	-0.01	-0.29	-0.02	-0.09	3.38	3.27	2.20	2.25
N17 AMSU-B	3	1090605	75.7	6997	111.9	-0.07	-0.06	0.12	0.10	3.54	2.56	0.98	0.84
	4	1090599	75.7	6753	113.5	-0.56	-0.52	-0.05	-0.03	3.00	2.30	0.91	0.82
	5	1090608	75.7	4007	124.8	-0.45	-0.40	-0.08	-0.04	2.40	2.03	1.07	1.01
N18 AMSU-A	5	118454	95.5	4682	93.1	0.02	0.08	0.06	0.07	0.28	0.25	0.20	0.19
	6	118454	95.5	4909	94.1	-0.14	-0.10	-0.07	-0.06	0.18	0.16	0.14	0.13
	7	118454	95.5	5317	93.8	-0.13	-0.10	-0.07	-0.07	0.23	0.20	0.17	0.16
	8	118454	95.5	20434	102.6	-0.01	0.02	0.01	0.01	0.27	0.22	0.19	0.17
	9	118454	95.5	20414	102.7	-0.05	-0.01	-0.03	-0.01	0.32	0.27	0.16	0.15
	10	118454	95.5	19410	104.4	-0.02	0.00	-0.01	-0.00	0.44	0.41	0.19	0.19
	11	118454	95.5	19204	104.8	0.01	0.01	-0.01	-0.01	0.72	0.68	0.36	0.34
	12	118454	95.5	18891	99.8	0.06	0.04	-0.05	-0.05	1.32	1.35	0.78	0.78
N18 AMSU-B	3	1083033	95.4	9041	123.4	-0.10	0.06	0.10	0.07	2.98	2.37	0.78	0.69
	4	1083018	95.4	8708	123.2	-0.53	-0.34	-0.00	-0.02	2.66	2.11	0.79	0.70
	5	1083027	95.4	5092	126.6	-0.57	-0.42	-0.14	-0.12	2.32	2.00	0.97	0.89

Table 6: Observation Summary for 3h 3D-FGAT **G003** (20090114 00 UTC - 20090131 18 UTC) of all analysis. * relative difference with respect to **G000** (6h 3DVAR).

7.2 Comparison against analyses

RMSE difference are summarized on following figures. There prevail mainly improvements, most pronounced above 700 hPa level and degradation are largely suppressed especially for 00 UTC forecasts. Noticeable is also at the moment unexplained difference between impact of 00 and 12 UTC forecasts, most probably coming from more frequent 3D-FGAT cycling.

7.2.1 Comparison against ECMWF analyses



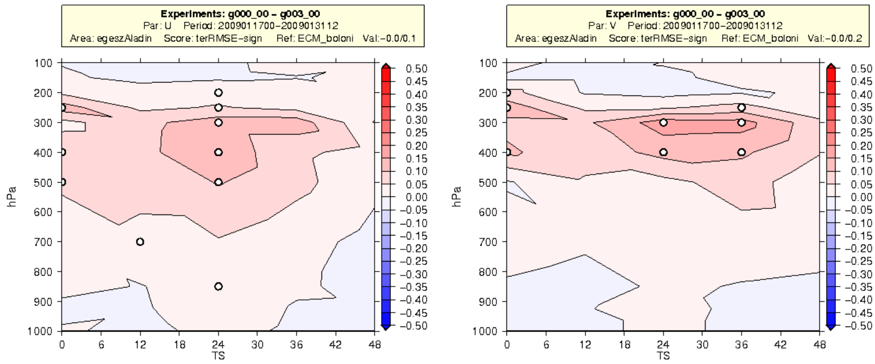
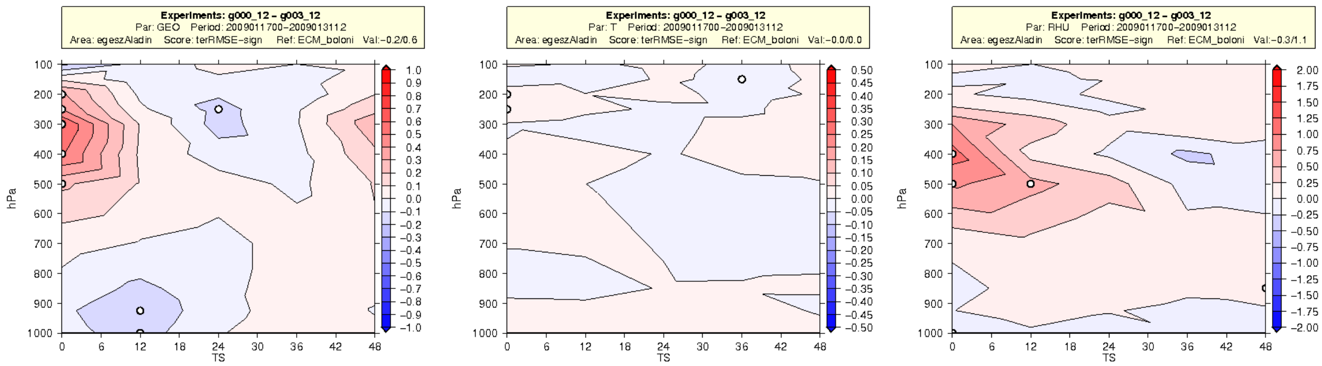


Fig. 29: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3DVAR (G000) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.



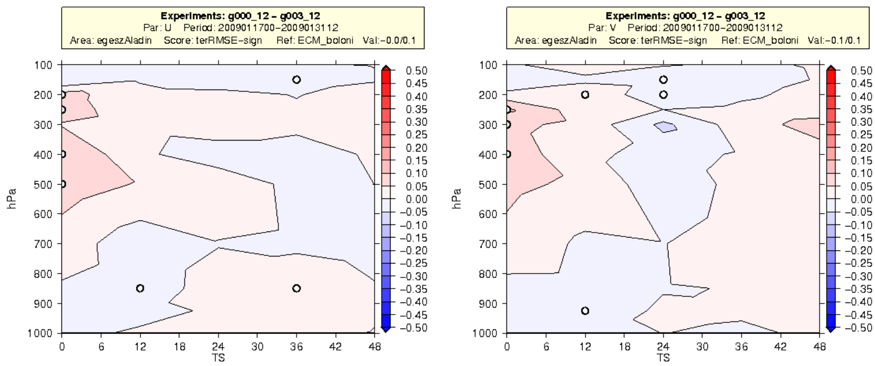


Fig. 30: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3DVAR (G000) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

7.2.2 Comparison against ARPEGE analyses

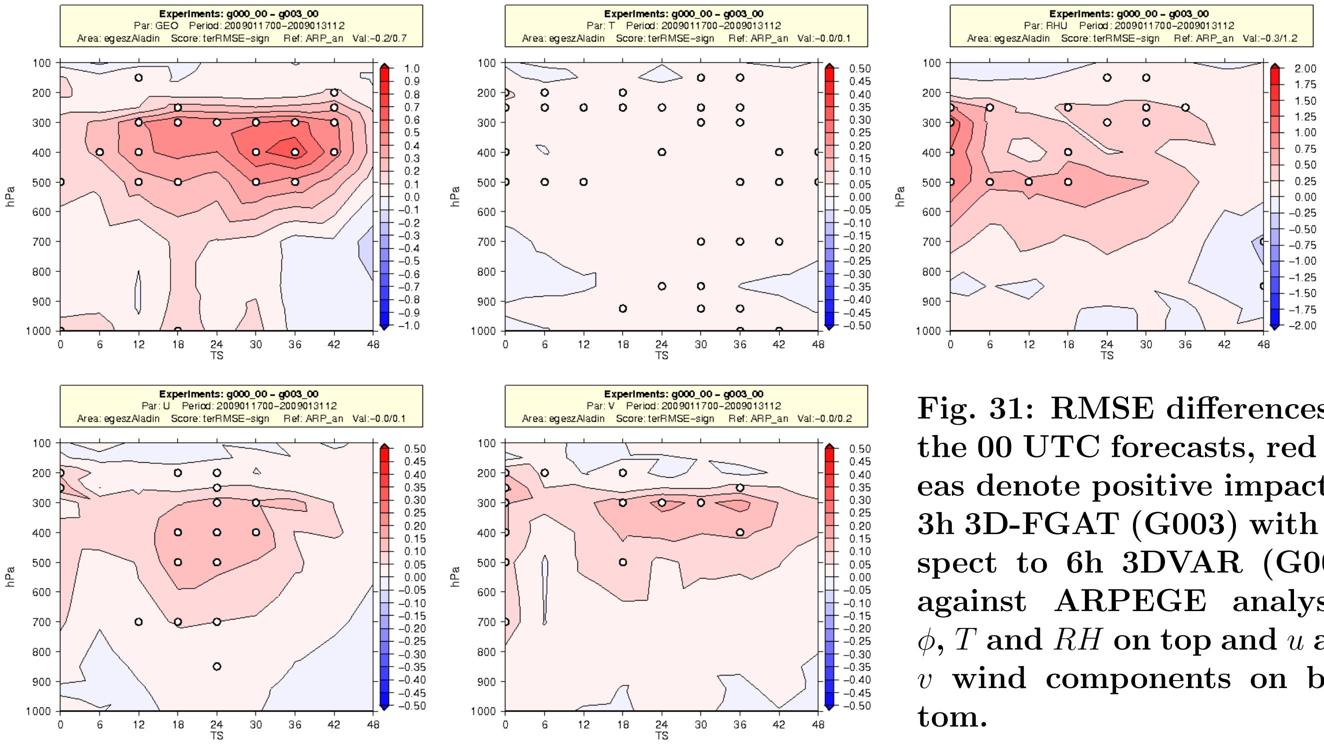


Fig. 31: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3DVAR (G000) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.

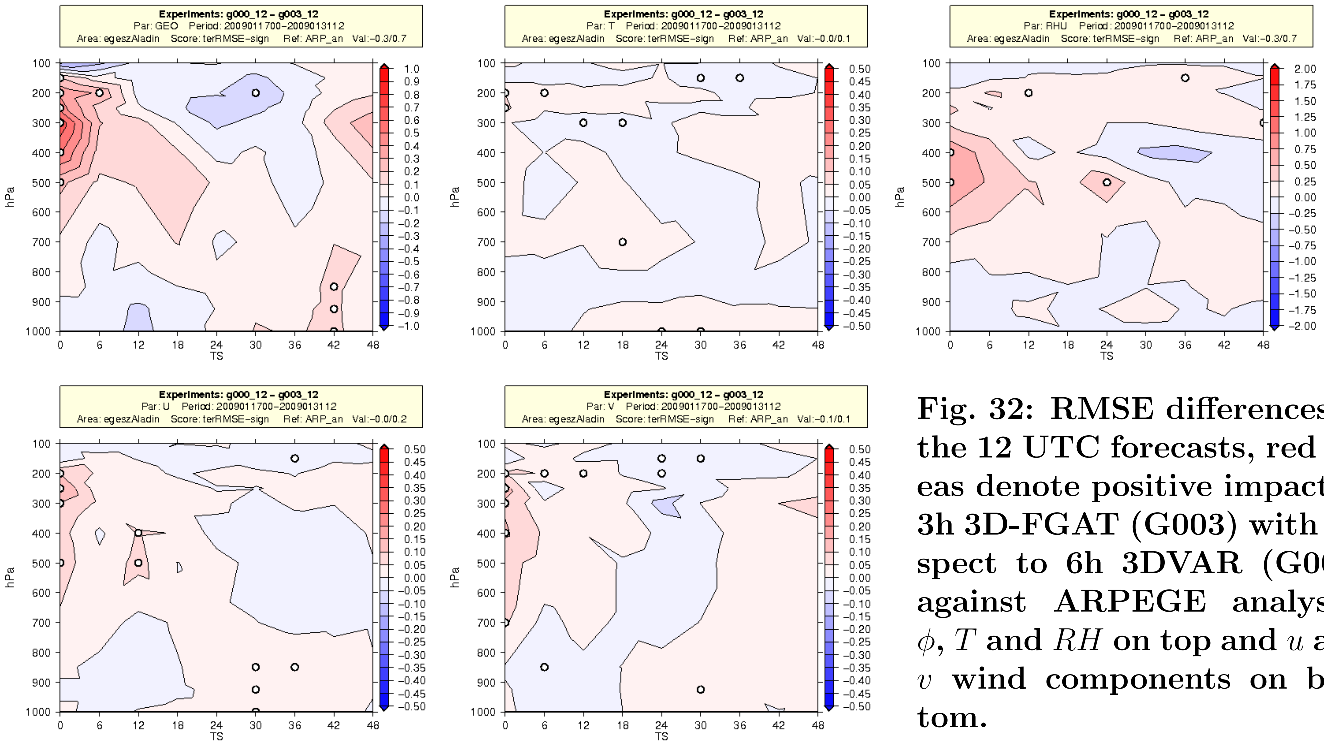


Fig. 32: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3DVAR (G000) against ARPEGE analyses, ϕ, T and RH on top and u and v wind components on bottom.

7.3 Comparison against observation

The statistics against observation show very small differences, noticeable is a little degradation around 150 hPa for geopotential. Complete summary of parameters and forecast ranges where 3h 3D-FGAT (G003) performs better (in green)/worse (in red) than 6h 3DVAR (G000) in terms of RMSE scores with significance 90% two side confidence interval significance test is summarized below. There prevail positive impacts especially in lower troposphere.

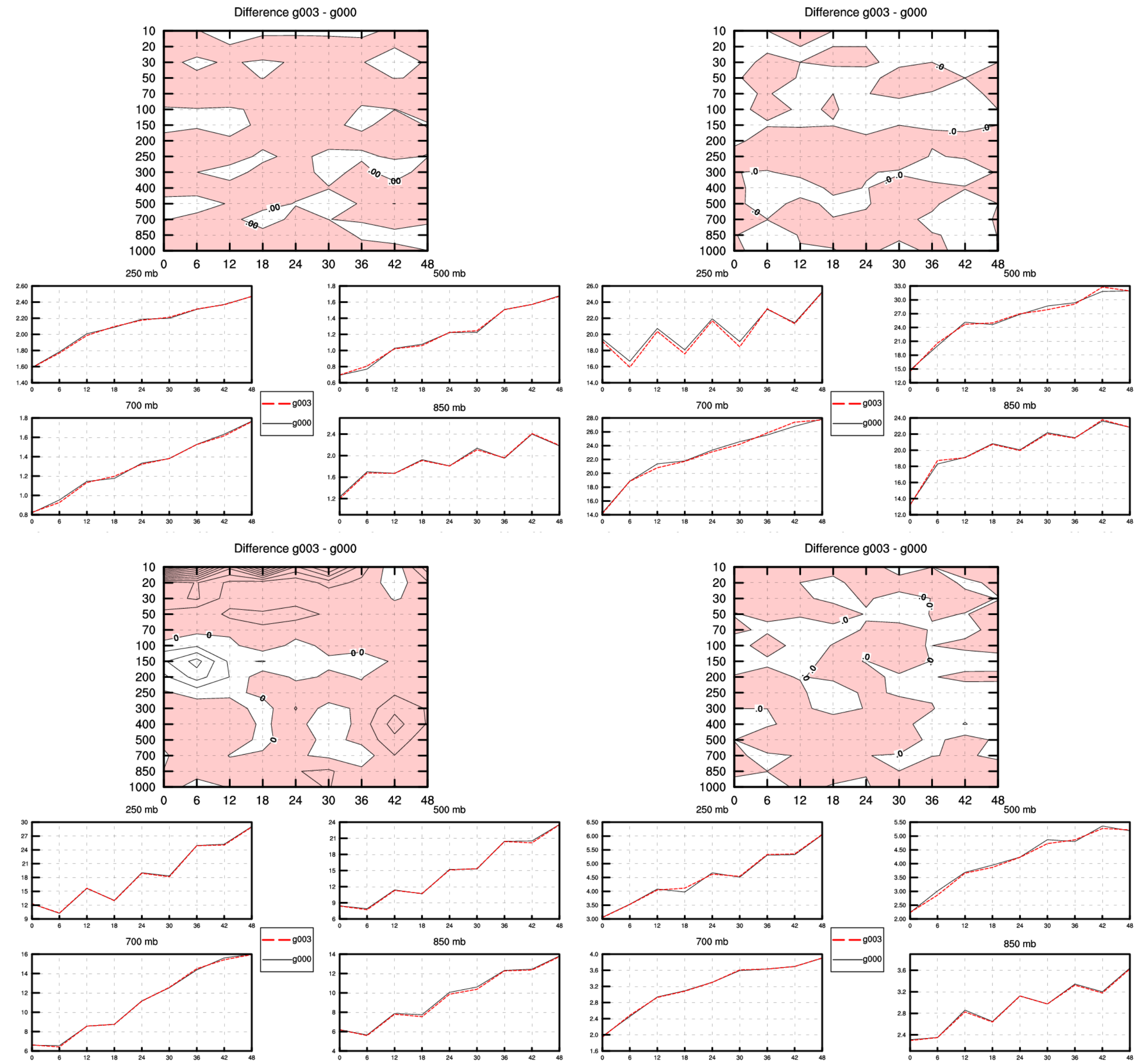


Fig. 33: RMSE of T and RH (top-left and right), ϕ and wind speed (bottom-left and right) red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 6h 3DVAR (G000) against TEMP.

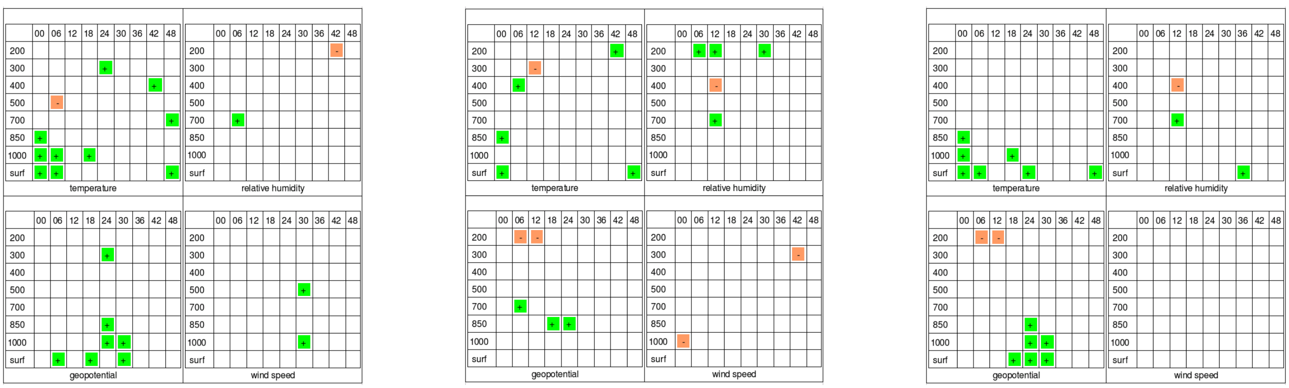


Fig. 34. List of parameters and forecast ranges where 3h 3D-FGAT (G003) performs better (in green)/worse (in red) than 6h 3DVAR (G000) in terms of RMSE scores against observation with significance 90% two side confidence interval significance test for 00 UTC productions (left), 12UTC productions (middle) and both 00 and 12 UTC (right).

8 Verification of precipitation

Forecast of precipitation were compared with observation (using local software OVISYS). The experiments were divided in two groups in an evaluation. The first set comprises all 3DVAR experiments and the second compare 6h 3DVAR with 6h and 3h 3D-FGAT. Following scores were checked and only for some of them , 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 score.

- Percent Correct (PC) is defined as the sum of the diagonal elements divided by the total number of events. Range of PC is zero to one, a perfect score is 1. Overall score can be greatly influenced by the most frequent categories (typically the "no event" case) and can thus give misleading information.
- False Alarm Ratio (FAR) is defined as the sum of "wrong" forecast divided by the number of forecast for each category. Range of FAR is one to zero, a perfect score is 0. 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. Range of POD is zero to one, a perfect score is 1.
- Bias or Frequency Bias (B) is defined as the number forecast divided by the number observed for each category. Range of B is zero to infinity, an unbiased score is 1. With B >1 (<1), the forecast system exhibits over-forecasting (under-forecasting) of the event. 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). Range of HSS is minus infinity to one, a perfect score is 1, no skill forecast is zero.

8.1 Impact of 3DVAR experiments

The first comparison contains all 3DVAR experiments:

- G005 - 6h 3DVAR without AMDAR filter
- G000 - 6h 3DVAR (with AMDAR filter)
- G001 - 3h 3DVAR (with AMDAR filter)

Time evolution of overall scores are displayed on figure Fig. 35. There were found only very small differences, if any.

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 POD, FAR, B and HSS scores were checked for each category. For most of categories the differences were very small, e.g. for no-rain category (<0.1mm) see Fig 36 and Fig 37.

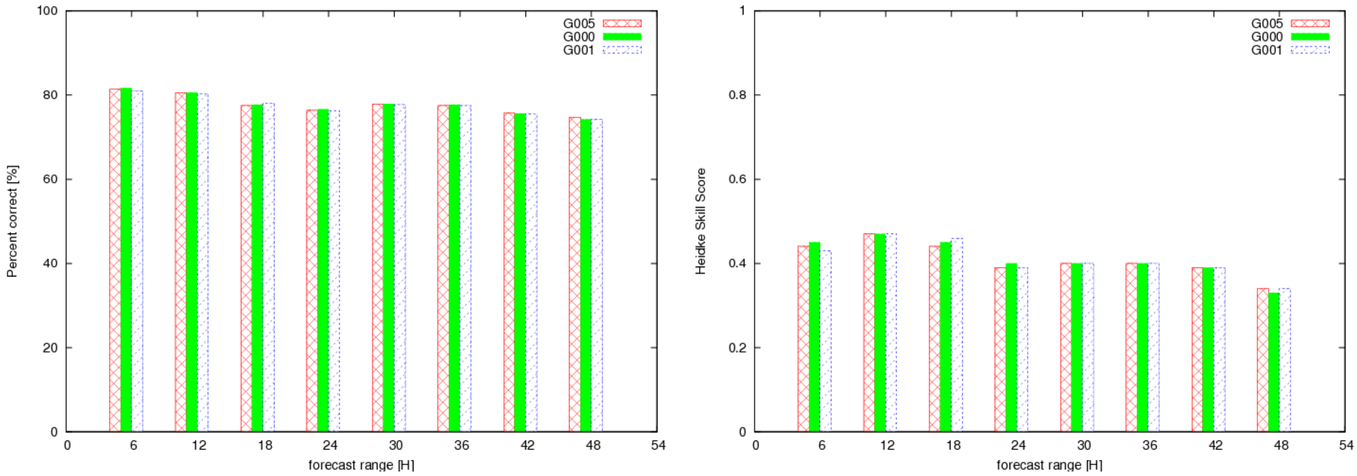


Fig. 35: Overall PC (left) and HSS (right) for 6h accumulated precipitations of 00 UTC forecasts. Experiment G005 in red, G000 in green and G001 in blue color.

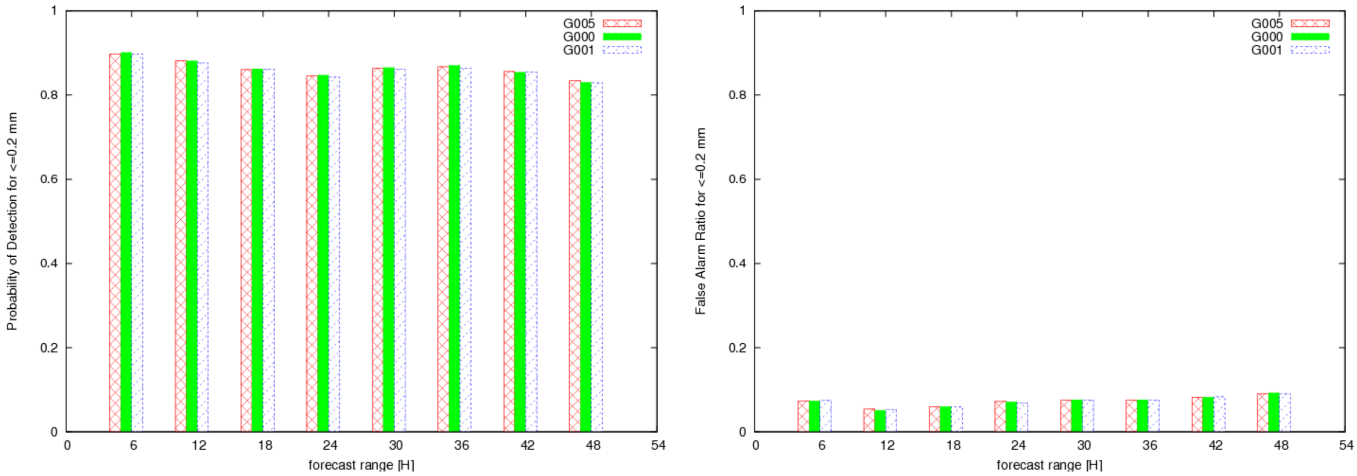


Fig. 36: POD (left) and FAR (right) for 6h accumulated precipitation $< 0.1mm$ of 00 UTC forecasts. Experiment G005 in red, G000 in green and G001 in blue color.

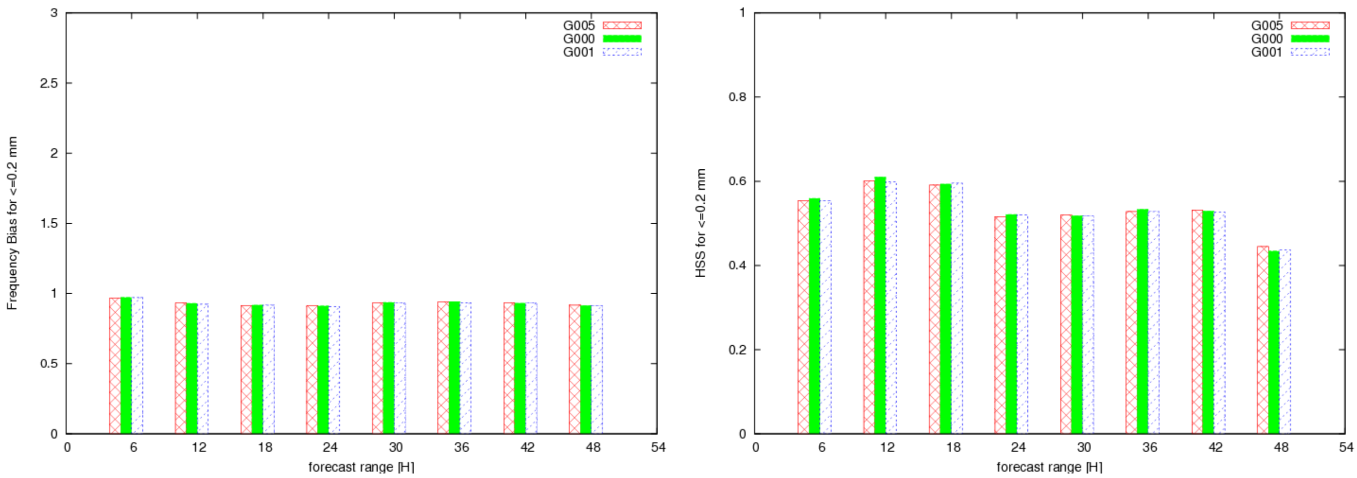


Fig. 37: B (left) and HSS (right) for 6h accumulated precipitation $< 0.1mm$ of 00 UTC forecasts.

The most noticeable differences were found for category of precipitation $> 10mm$, where 3h 3DVAR showed an increase of POD (while decreasing FAR) for the first forecast ranges (up to +18H). A little improvement can be found for B and several ranges of HSS.

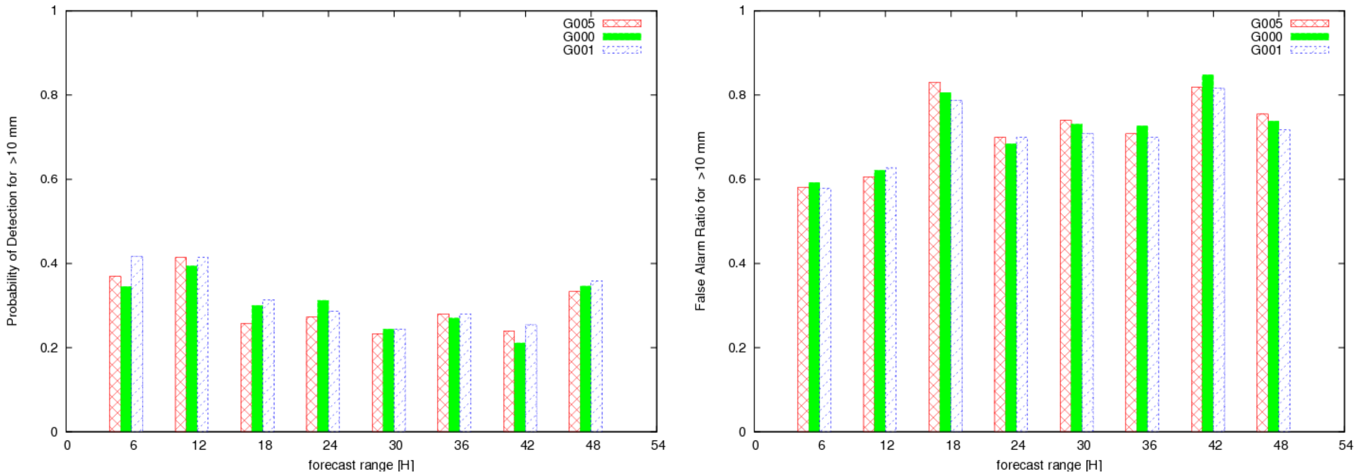


Fig. 38: POD (left) and FAR (right) for 6h accumulated precipitation $> 10mm$ of 00 UTC forecasts.

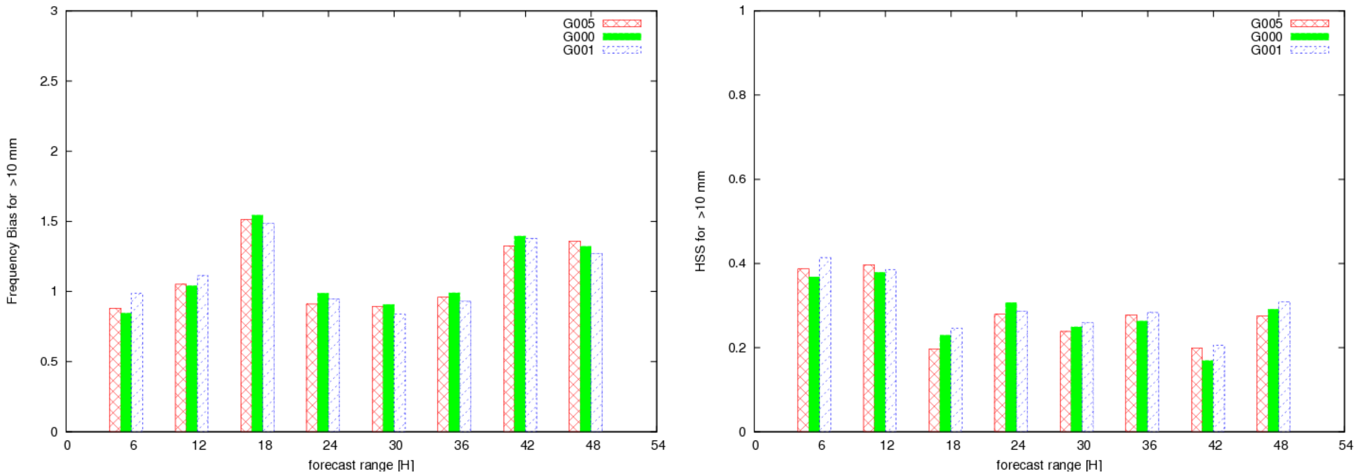


Fig. 39: B (left) and HSS (right) for 6h accumulated precipitation $> 10mm$ of 00 UTC forecasts.

Unfortunately the same trend was not found for forecast from 12UTC forecasts. There was almost no improvement of POD, but characteristic was rather over-estimation of precipitation for the first hours of the forecast, confirmed by increase of B and FAR.

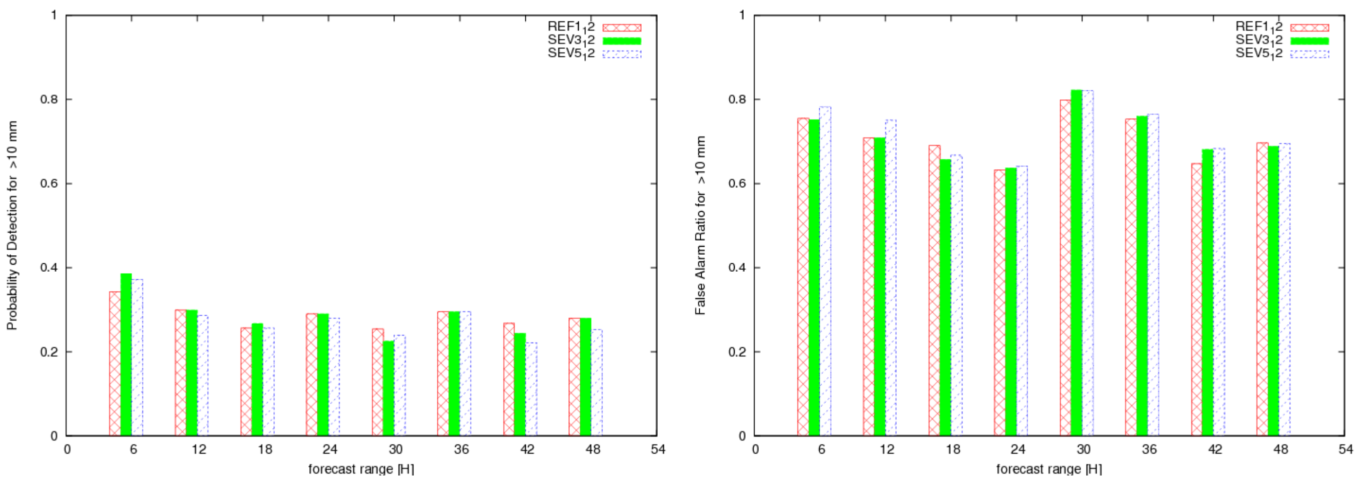


Fig. 40: POD (left) and FAR (right) for 6h accumulated precipitation $> 10mm$ of 12 UTC forecasts.

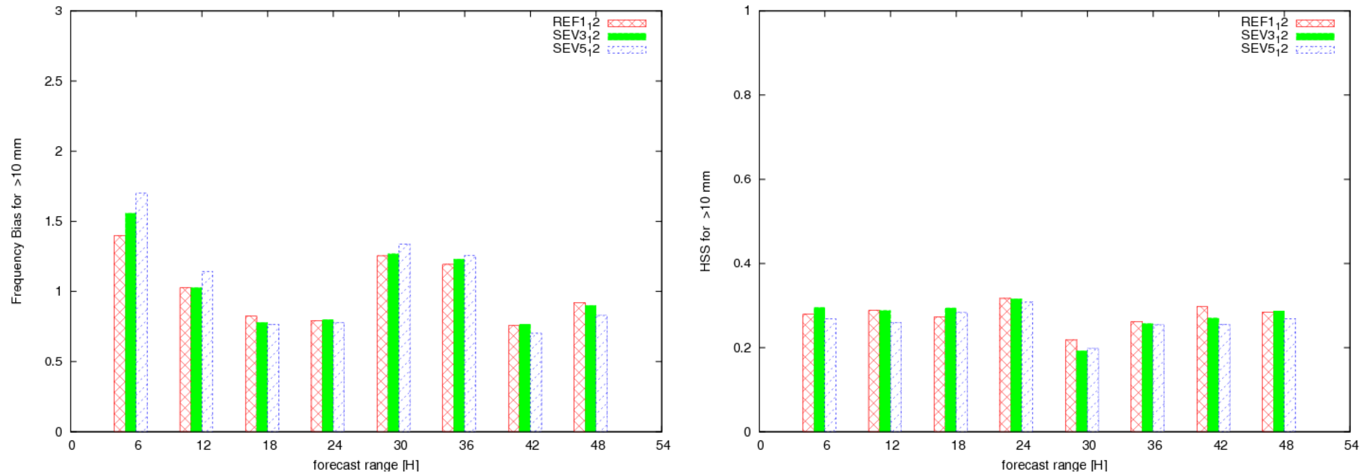


Fig. 41: B (left) and HSS (right) for 6h accumulated precipitation $> 10mm$ of 12 UTC forecasts.

8.2 Impact of 3D-FGAT experiments

This evaluation compares the 3D-FGAT experiments with respect to 6h 3DVAR without AMDAR filter.

- G005 - 6h 3DVAR without AMDAR filter
- G002 - 6h 3D-FGAT without AMDAR filter
- G003 - 3h 3D-FGAT without AMDAR filter

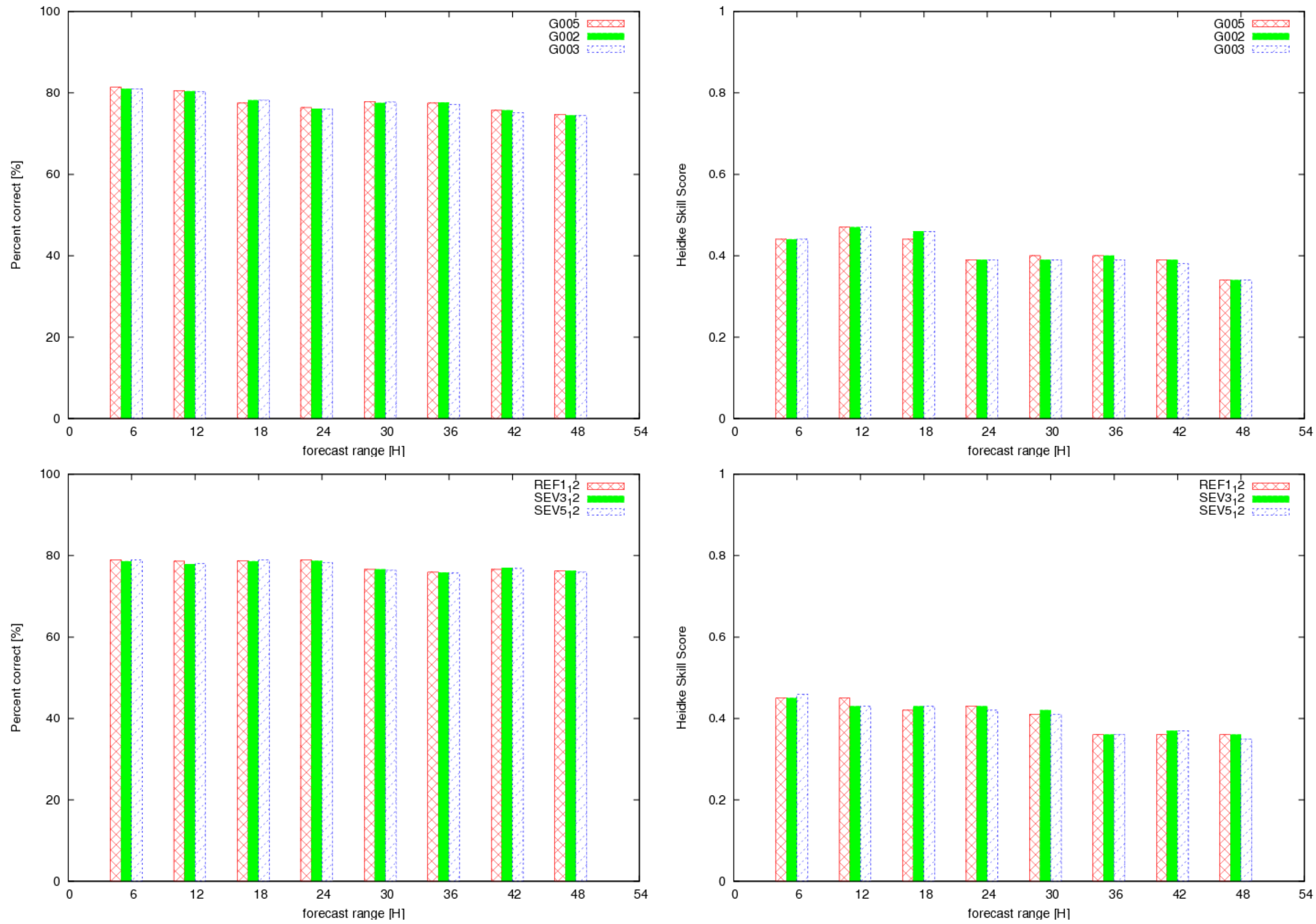


Fig. 42: Overall Percent Correct (left) and Heidke Skill Score (right) for 6h accumulated precipitations for forecasts starting from 00 UTC runs (top) and 12 UTC (bottom). Experiment G005 in red, G002 in green and G003 in blue color.

In the over all scores a very small improvement can be found for +18H forecast range for both PC and HSS of 00 UTC runs, but also degradation of HSS for +30H. Generally in the comparison of 3D-FGAT experiments the overall scores showed very small differences without clear signal.
Most noticeable differences were found again for category of heavy precipitation $> 10mm$.

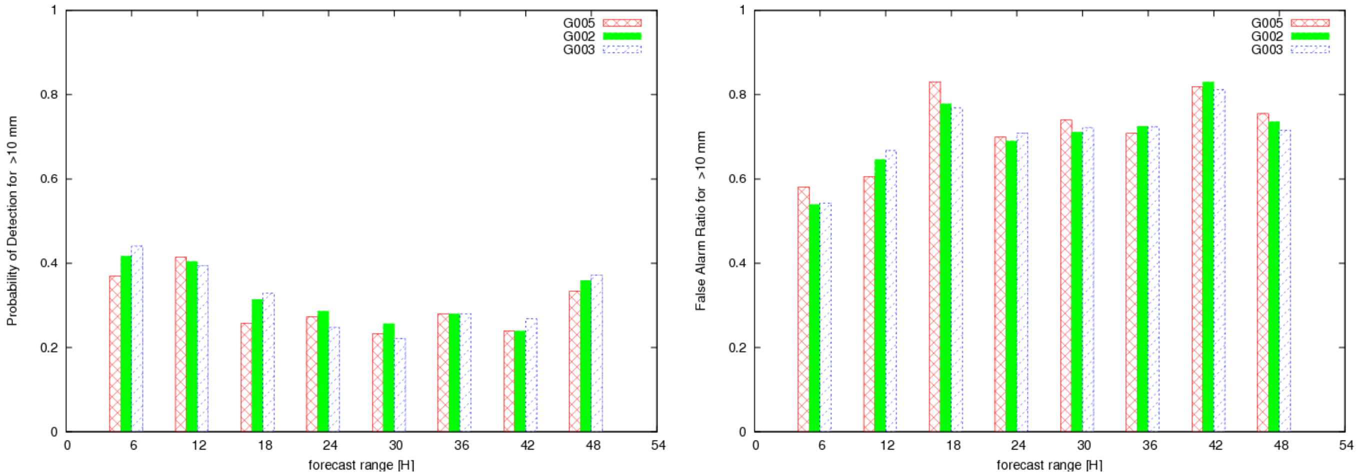


Fig. 43: POD (left) and FAR (right) for 6h accumulated precipitation $> 10mm$ of 00 UTC runs.

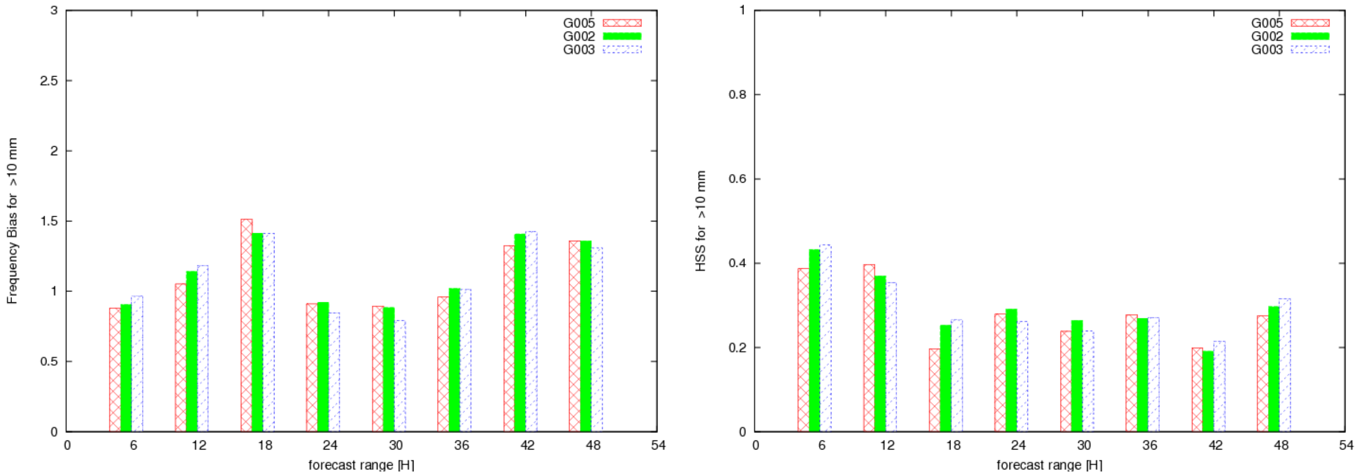


Fig. 44: B (left) and HSS (right) for 6h accumulated precipitation $> 10mm$ of 00 UTC runs,

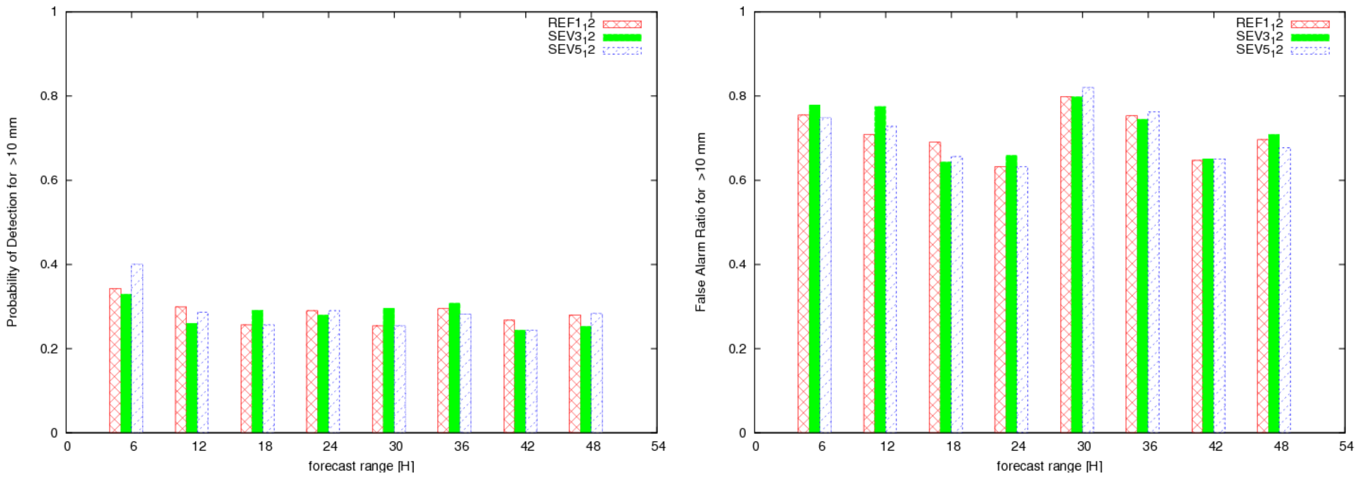


Fig. 45: 12UTC POD (left) and FAR (right) for 6h accumulated precipitation $> 10mm$ of 12 UTC runs.

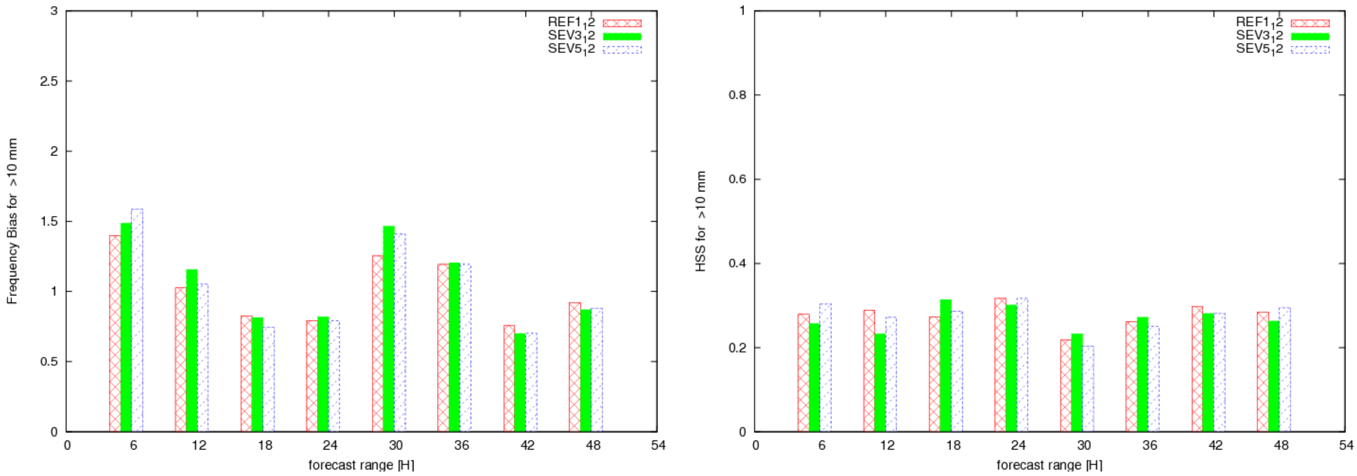


Fig. 46: 12 UTC B (left) and HSS (right) for 6h accumulated precipitation $> 10mm$ of 12 UTC runs.

The 6h 3D-FGAT experiment exhibits mostly an increase of POD (except of +12H forecast range) for 00 runs, while the signal is not so clear for 12 UTC runs. FAR scores decrease for the first +36H (again except of 12H forecast range) for 00 UTC runs, while for 12 UTC runs there is an increase of FAR for the first two forecast ranges. HSS score is mostly a little bit better (except of +12H,+36H,+42H forecast range) for 00 UTC runs, while for 12 UTC runs 6h 3D-FGAT is better only for couple of ranges (+18H,+30H,+36).
The 3h 3D-FGAT experiment showed quite similar results to 6h one, in some cases with even better performance, but in other cases with deteriorated one.

9 Summary

More frequent 3DVAR cycling (RUC) showed mainly improvement, especially in upper troposphere, but worrying is a degradation of geopotential at the end of forecast for 00 UTC. The scores are generally more pronounced for 00 UTC forecast, which would be desirable to better understand. Comparison against observation showed statistically significant improvements for several forecast ranges mainly below 850 hPa.

More frequent 3D-FGAT cycling showed rather encouraging comparison against observations were prevailed mainly positive impact in lower troposphere and for near surface parameters. But the scores against analyses didn't show clearly positive impact. The impact was rather positive for 00 OTC forecasts, while rather negative for 12 UTC ones. More time should be dedicated to understanding the analyses results.

Impact of 3D-FGAT experiments confirmed previous findings of rather small differences in terms of overall verification scores. In the first comparison (G002 vs G005), the impact could be attributed mainly to satellite data (monitoring showed increase of active data about 0.4% for aircraft data and about 10-70% for radiance), the scores exhibited very small differences, the improvements were mostly above 700 hPa level (especially around 400 hPa), while degradations were found in lower levels mainly for temperature, geopotential and wind speed. In the next comparison (G002 vs G000), the impact could be attributed both to satellites and aircraft data (monitoring showed about 59% more active aircraft data and about 10-70% of radiance), the scores showed a bit bigger improvement than in the first FGAT comparison, obviously coming from the additional AMDAR observation, but again impact is mostly above 700 hPa level (especially around 400 hPa), while degradations below. In both experiments comparison against SYNOP and TEMP observations were rather neutral. Last comparison of 3h 3D-FGAT with 6h 3DVAR (G003 vs G000) added to previous experiment an impact of extra SYNOP, AMDAR, SATOB and wind-profiler observations coming from more frequent analysis cycling. In the scores prevailed mainly improvements, still mostly pronounced above 700 hPa, but the degradations below were largely suppressed. Also comparison against observation showed mainly statistically significant improvements for several forecast ranges, for lower troposphere in particular.

Although special attention was given to verification of precipitation, clear results were not obtained. The overall scores exhibited very small differences, if any. And rather contradicting results were obtained for 00 and 12 UTC runs.

To conclude the most promising from tested configurations seems to be 3h 3DVAR. The 3D-FGAT showed capability to improve performance of 3DVAR in higher troposphere especially, but has deficiencies mainly in lower troposphere. An interesting would be an investigation of assimilation of near surface parameters (2m measurements and/or 10m wind) or some low peaking satellite channels. Also better understanding of 3D-FGAT behavior would be desirable, there were encountered some unexplained features in observation usage statistics and different impact for 00 and 12 UTC. The 3D-FGAT features could be demonstrated on the next Fig .47 and Fig. 48 where 3h 3D-FGAT was compared with 3h 3DVAR. When considering an operational application of various configuration one should keep in mind also CPU costs, which are about only 70% for double frequency 3DVAR and about 350% for 3h 3D-FGAT.

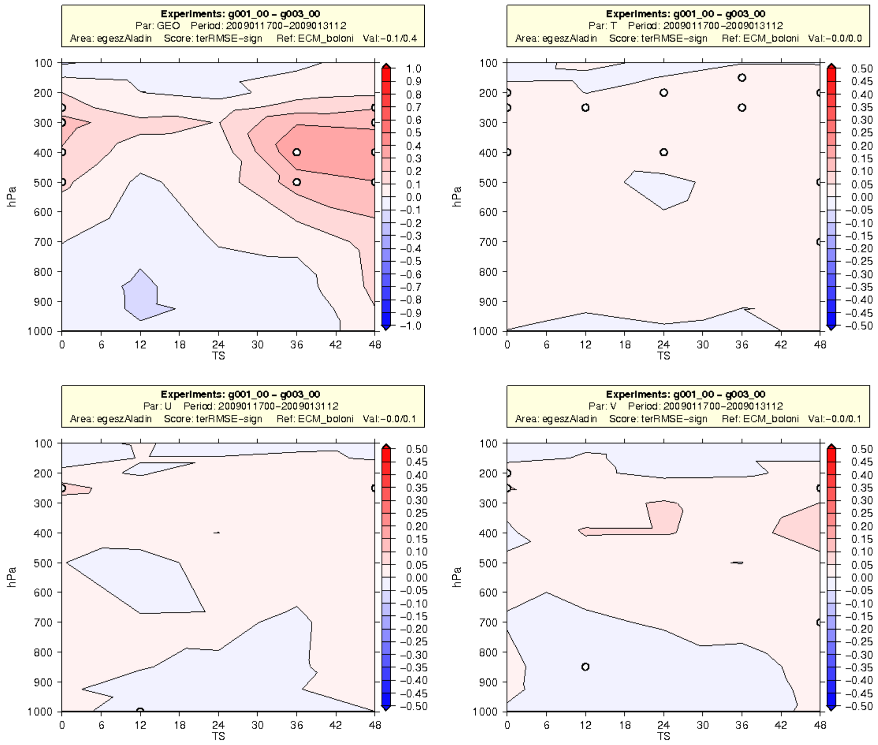


Fig. 47: RMSE differences of the 00 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 3H 3DVAR (G001) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

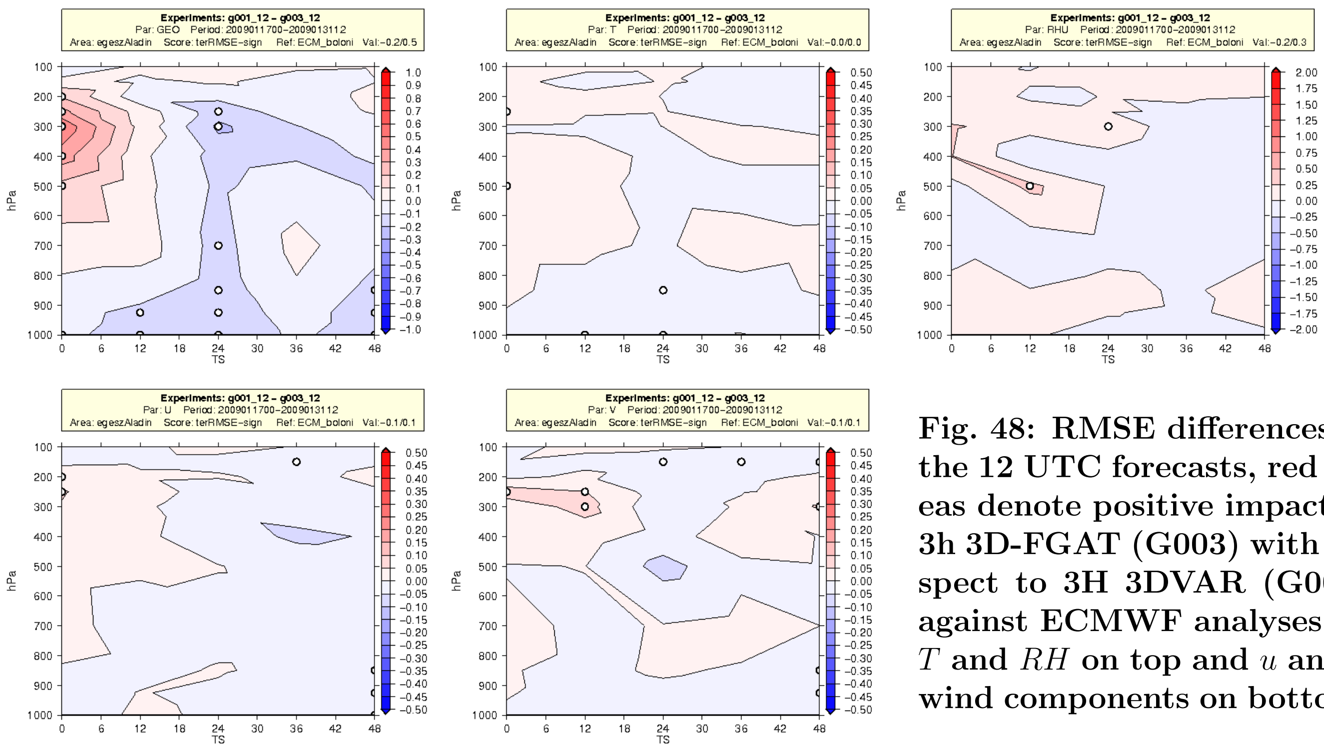


Fig. 48: RMSE differences of the 12 UTC forecasts, red areas denote positive impact of 3h 3D-FGAT (G003) with respect to 3H 3DVAR (G001) against ECMWF analyses, ϕ, T and RH on top and u and v wind components on bottom.

10 Acknowledgments

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Appendix

A Technical notes

The experiments were performed on cycle 30t1, operational scripts for assimilation was adopted. The scripts are stored on atroja@3700a in scr directory, namelists in nam and constant files in Const.

Following items were essential in preparation of experiments:

- all LBCs were prepared in advance and stored in /rtovol4/atroja/archive/lbc/ as the same files are used in all experiments.

  1. to get ECMWF the first two LBCs for assimilation lunch
  - ./get_assim_lbc.ksh (in case the files are in high resolution on archive (due to an error in oper suite))
  - lancelot_assim_f000 (otherwise), uses lanca_date_f000 and lastlanca_date_f000

  2. to get ECMWF LBCs last LBC (+006) for assimilation and all LBCs for production (+009 - +054) lunch
  - lancelot_prod_f000 (uses lanc_date_f000 and lastlanc_date_f000)

  3. use function RunCheckLbcArchive insead of RunCheckLbc to get prepared LBCs

- to use OPLACE observation run function RunGetObsOPLACE instead of RunGetObs and RunOulan. Input data are stored in /rtovol4/atroja/pplace_chmi/

- the guesses were prepared in advance (to ensure continuity) by script Guess_g000 and are stored in /rtovol4/atroja/archive/g000/production/2009/01/13/18/
  ICMSHg000+0036tsteps ... +3H = guess for 6h and 3h 3DFGAT
  ICMSHg000+0072tsteps ... +6H = guess for 6h 3DVAR (reference) and 3h 3DVAR (RUC)
  the files should be linked to corresponding working directories
  /vol1/atroja/$CNMEXP1/assim/guessdir

- preparation of the very first guess. Directory and file has to be prepared MANUALLY !

  atroja@3700a: /scr CNMEXP1=f000
  atroja@3700a: /scr mkdir -p /vol1/atroja/$CNMEXP1/assim/guessdir
  atroja@3700a: /scr cp /rtovol4/atroja/archive/assim/2009/03/05/00/ICMSHALAD+0006 /vol1/atroja/f000/assim/guessdir/guess_2009030506

- the experiments differs in Assim and Morgane (includes short cut-off assimilation !) scripts:

  - Assim_$EXPFILE (uses assim_date_$EXPFILE and lastassim_date_$EXPFILE)
  - Prod_$EXPFILE (uses prod_date_$EXPFILE and lastprod_date_$EXPFILE)

Summary of experiments:

- g000 - 6h 3DVAR with OPLACE observation
  - observation selection: obstype obsoul_[1,5,6,3]_*$slot4* obsoul_2_*$slot3* obsoul_2_*$slot4* obsoul_2_*$slot5* obsoul_7_* and grib_7_seviri_xx_$slot4.gz)

- **g001 - 3h 3DVAR with OPLACE observation**
  - observation selection: obstype obsoul_[1,5,6,3]_*$slot4* obsoul_[2,7]_*$slot3* obsoul_[2,7]_*$slot4* obsoul_[2,7]_*$slot5* and grib_7_seviri_xx_$slot4.gz)
  - script based on g000 only modification is cycling every 3h and obs extraction !

- **g002 - 6h 3D-FGAT**
  - observation selection: same as in g000
  Due to technical problems:
  – switch off Amdar filter (LFILTAMD=0 include.in_g002)
  – default PROC_LAMFLAG=/home/aladin/workdir/pack/cy30t1_main.01.ifort9_2B2.x.pack/bin/LAMFLAG_ODB
  - new procedure to shift increments RunShiftIncr (PROC_ADDINCR=/home/atroja/pack/op02/bin/ADDINCR)
  - CreateGuess only for +3H

- **g003 - 3h 3D-FGAT**
  - observation selection: same as in g001
  - script based on g002 with modification for 3h cycling (LBCs treatment, no CreateGuess)

NB: Do not forget that Prod scripts contains short cut-off assimilation !!!

All scripts and constant files should be in /home/atroja/src, nam or Const. All results (oper,G000,G001,G002,G003) are stored in /rtovol4/atroja/archive/$EXP/ (Some results (oper,G000) were already moved to archive (by IT department ask Miklos for details)). Listings from jobs are stored in /rtovol4/atroja/Listings and input OPLACE observation in /rtovol4/atroja/pplace_chmi.