Assimilation of SEVIRI data II

report from LACE stay in Budapest, 23/1/07-17/2/07

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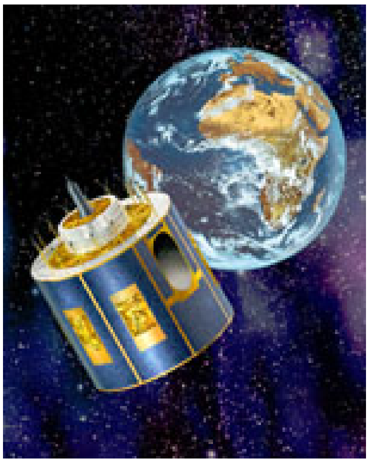

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1 Introduction

In autumn 2006 during our common LACE stay with Michal Májek, SEVIRI data were successfully assimilated in ALADIN/HU 3DVAR system, local data processing was developed and also the first impact studies were performed. The impact of SEVIRI data was found promising and require further investigation. This study was dedicated to "refinement" of SEVIRI data use in ALADIN/HU 3DVAR system. The report is organized as follows: in the next section considered tuning parameters are described, in Section 3 performed impact studies are summarized and in the last section conclusion and future plans are drawn.

2 Tuning

Concerning tuning of given observation type usage in 3D VAR system there are obvious component to be considered and they will be briefly presented in this section. In this study we have followed the development of Montmerle (2005a) thus the details of SEVIRI data use as observation operator, thinning or bias correction are not considered.

2.1 Background errors

Background error covariance matrix B filters and propagates the information given by the increment and its good choice is very important for any assimilation system. So far we used in our experiments B matrix derived by the standard NMC method that computes the model error covariances from statistics on the set of differences of model forecast valid at the same time (+12H and +36H forecasts). It was shown by Berre *et al* (2006) that ensemble method of deriving B matrix, which uses an ensemble of 6H ALADIN forecasts performed from an ensemble of ARPEGE analysis computed from perturbed observations, can more accurately represent the analysis effects, in particular, more realistic error correlation spectra.

The ensemble B matrix was used in the implementation of SEVIRI data at Météo France as reported by Montmerle (2004) and in near future will be also operational in ALADIN/HU 3D VAR system. Thus the ensemble B was considered as one of the first tuning parameter for this study. The mean vertical variances of the background errors for control variables are on Fig 1. There are apparent lower values of ensemble based statistics.

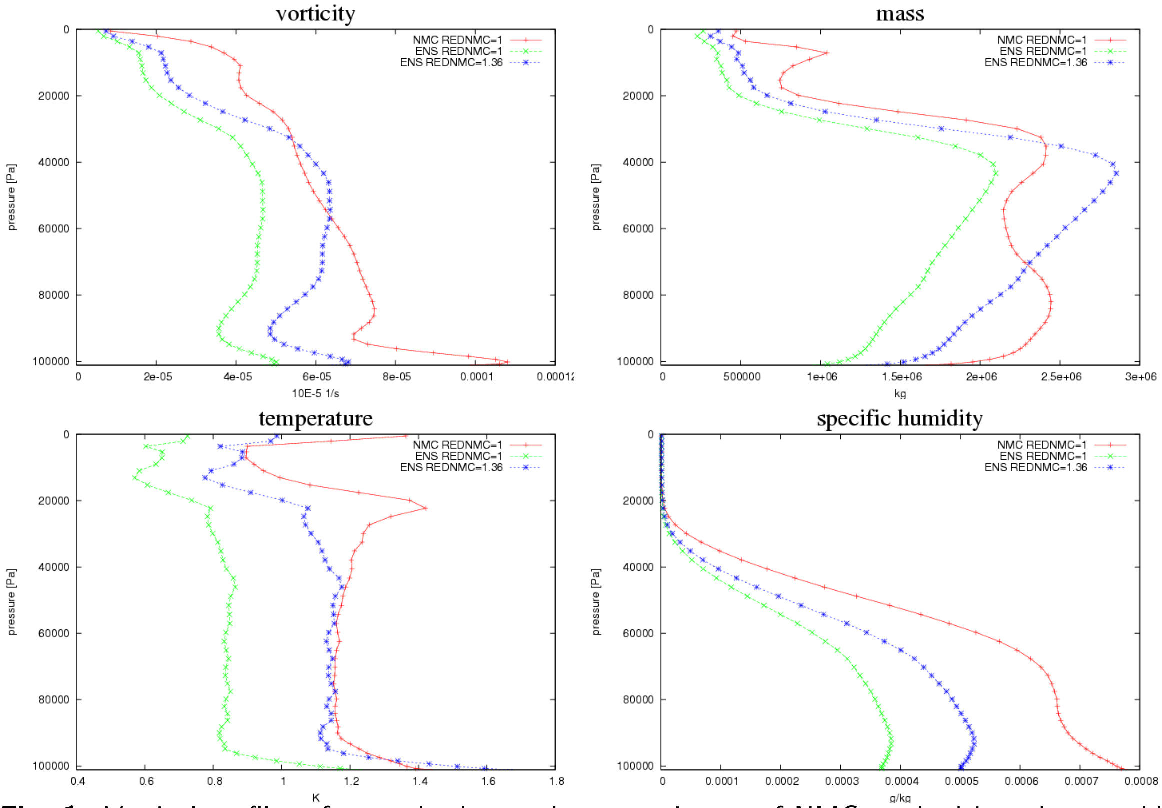

Fig. 1: Vertical profiles of mean background error variances of NMC method in red, ensemble in green and ensemble one with REDNMC=1.36 in blue.

Further tuning can be performed by the REDNMC factor, which allows empirically increase/decrease the background standard deviation σ_b. As the B matrix influence all the observation types there are not so many options on this item for tuning of SEVIRI observation only.

2.2 Observation errors

Observation error covariance matrix R contains instrumental errors and errors of the observation operator H. Errors of different observations are assumed to be uncorrelated and R is then diagonal.

We focused more on the tuning of observation errors as our subject is just one particular type of satellite data and moreover its analysis is not directly related to the control variables in ALADIN 3D VAR. Default observed brightness temperature errors for 8 SEVIRI channels (3.9 μm, 6.2 μm, 7.3 μm, 8.7 μm, 9.7 μm, 10.8 μm, 12.0 μm, 13.4 μm) are following

$$\sigma_o = (1.05, 1.70, 1.70, 1.05, 1.05, 1.05, 1.05, 1.05)$$

As pointed by Montmerle (2005), the uncertainty of the humidity estimation in the troposphere leads to take a larger σ_o for the two WV channels.

2.2.1 "Intuitive" tuning

Monitoring statistics as average mean and standard deviation of obs-guess and obs-analysis can provide an information about how much are given data type taken into account during analysis. On Fig 2. there are statistics for experiments which differs only in σ_o for SEVIRI channels. There is apparent as the σ_o decreased the distance of mean obs-analysis and obs-guess is increasing, which means that more information is coming from the SEVIRI data or that we believe more on SEVIRI data. There is no quantitative measure, how much or in which direction σ_o should be tuned and hence following method was studied.

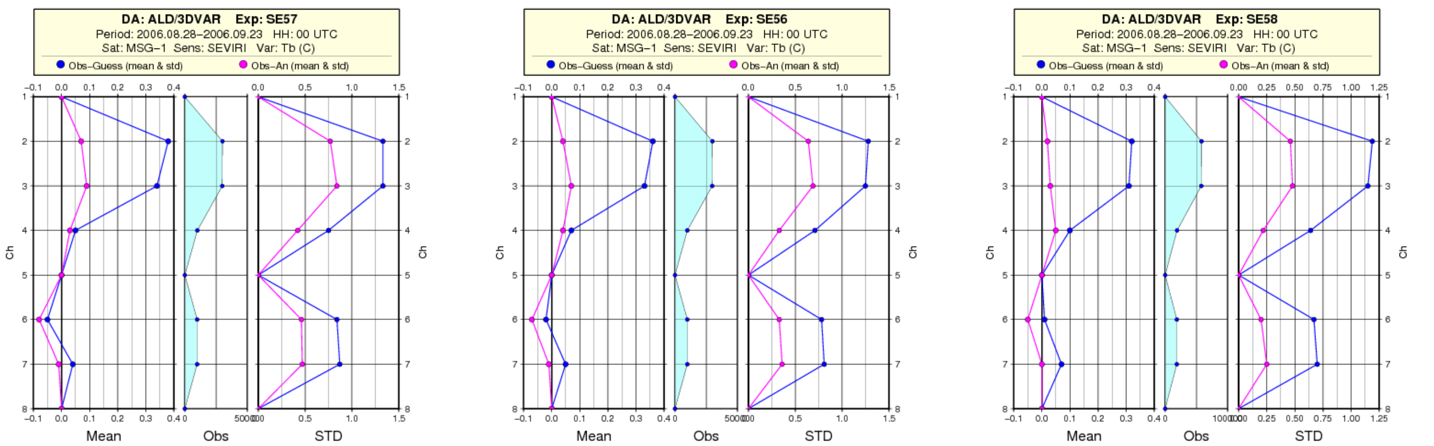

Fig. 2: Monitoring statistics for SEVIRI channels with σ_o +40 % (left), default σ_o (middle) and σ_o - 40% (right). In each graph mean (left) and standard deviation (right) are presented.

2.2.2 "Desroziers *et al*" method

On the basis of linear estimation theory Desroziers *et al* (2005) proposed simple diagnostics which should be fulfilled in an optimal analysis. For any subset of observations i with p_i observations one can compute diagnosed value of observation and background error

$$(\sigma_i^o)^2 = \sum_{j=1}^{p_i} \frac{(y_j^o - y_j^a)(y_j^o - y_j^b)}{p_i}$$

$$(\sigma_i^b)^2 = \sum_{j=1}^{p_i} \frac{(y_j^a - y_j^b)(y_j^o - y_j^b)}{p_i}$$

An advantage of proposed method is that the diagnostic is quite simple and cheap to compute. Those diagnostics could provide an information on imperfectly known observation and background error statistics.

Diagnosed values of observation error were computed for analyzes produced by ALADIN/HU 3DVAR system and compared with prescribed observation error currently used in the model. The statistic were computed as an average for 27 days from 20060828 00 UTC till 20060923 00 UTC. We have noticed that some departures $(y^o_j - y^a_j)$ and $(y^o_j - y^b_j)$ have different signs, which means that analysis is state not between guess and observation state and it can be considered as probably wrong analysis behavior. Those points were skipped from the statistic computations. Following figure shows comparison of obtained diagnostics for SEVIRI instrument and prescribed observation errors. The diagnostics for other observations can be found in Appendix A.

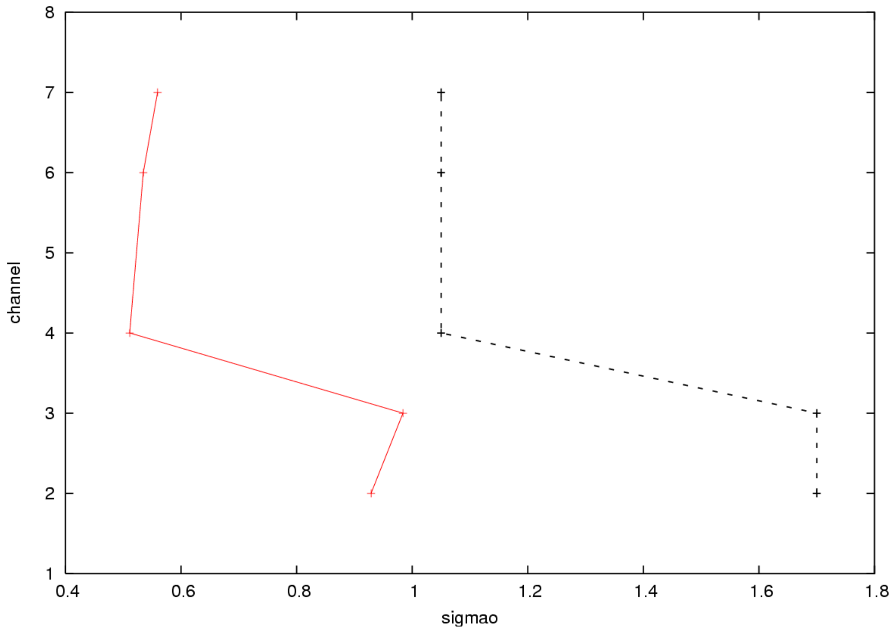

Fig. 3: Diagnosed (as red full line) and default observation errors (as black dashed line) for different SEVIRI channels.

Diagnosed observation errors indicate that used observed brightness temperatures error for all channels seem to be almost doubled in the analysis, the over-estimation is common to most of the other observation types too.

3 Impact studies

All experiments were performed with 3D-VAR ALADIN/HU described in details by Boloni (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 following the standard NMC 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 radiances)
- 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 mostly in adding SEVIRI data, tuning its observation errors or used B matrix. Way of SEVIRI data use was based on Montmerle (2005a), 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 applied during screening and air-mass bias correction as described in Trojáková and Májek (2006) was applied in all experiments. For computation of our experiments we took period from 20060826 00 UTC till 20060923 12 UTC. First 2 days were taken for warming up of assimilation cycle and the rest 27 days for impact studies. All experiments started from the same first guess at 20060826 00 UTC. We provided 48 hours forecast from 00 analysis.

3.1 Bug-fixes

Due to bugs (wrong blacklisting of SYNOP and TEMP observations, poor extraction of AMSU-B radiances and mismatched setting of vertical diffusion) found in the experimental settings after previous stay. Reference and an experiment with added SEVIRI were rerun and will be presented as:

- **REF2** - SYNOP, TEMP, AMDAR, ATOVS, AMV observations with NMC B matrix
- **SE55** - REF2 + SEVIRI

3.1.1 Discussion and results

Comparison against observations shows very small differences on RMSE scores as can be seen on Fig 4.

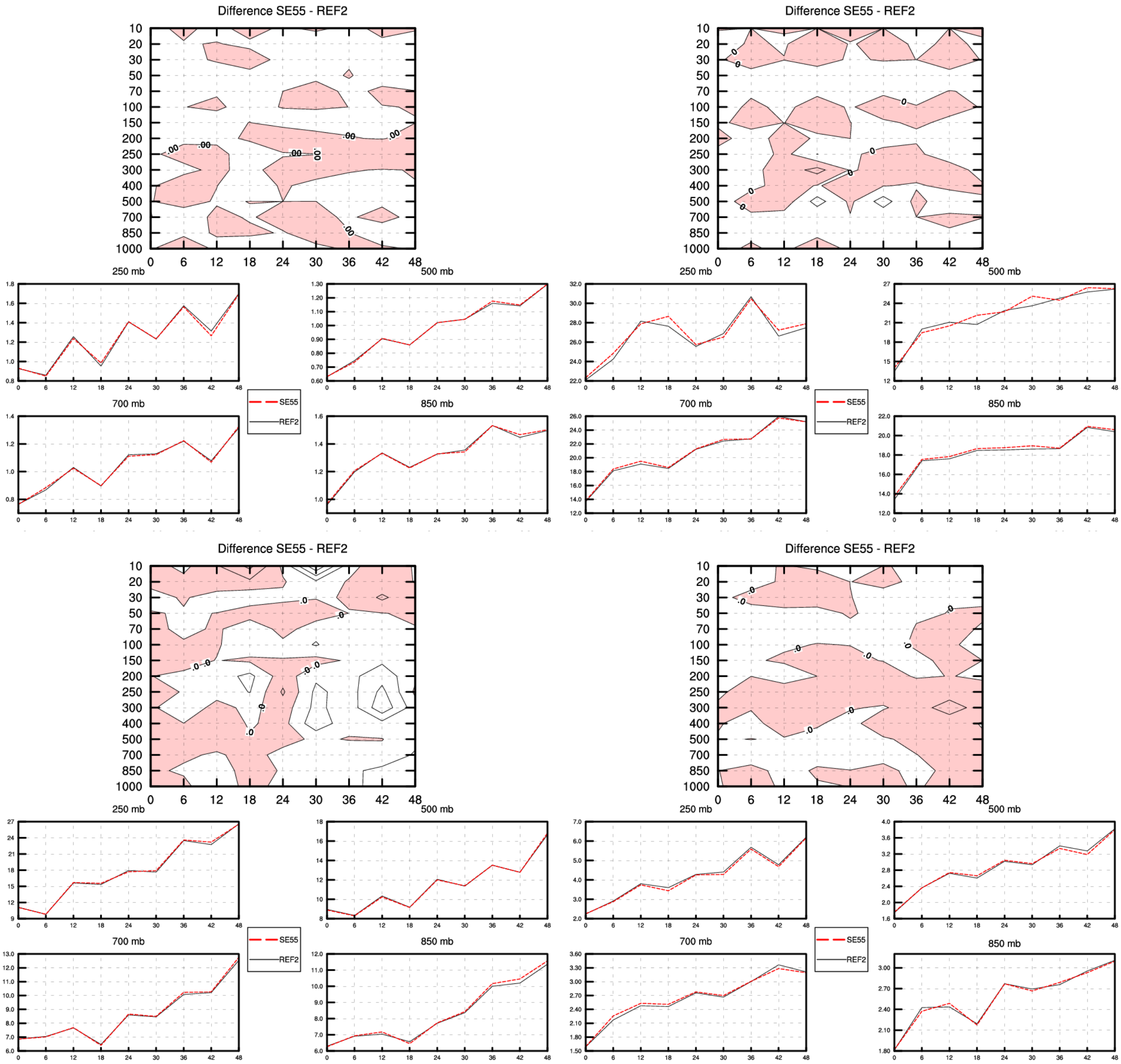

Fig. 4: RMSE of T (upper-left), RH (upper-right), ϕ (bottom-left) and wind speed (bottom-right) from 20060828 till 20060923 of 00 UTC runs. Red areas denote positive impact of SEVIRI usage.

Significance test proved negative impact to be significant for some ranges of relative humidity up to 400 hPa, also degradation of geopotential between 850 and 400 hPa, for full list see Table 1.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+06H	worse	ϕ 850 hPa	+48H	worse
	+30H	worse	RH 850 hPa	+00H	worse
	+36H	worse	ϕ 700 hPa	+48H	worse
ϕ 1000 hPa	+12H	worse	RH 700 hPa	+12H	worse
	+36H	worse	ϕ 500 hPa	+48H	worse
	+48H	worse	RH 500 hPa	+00H	worse
RH 1000 hPa	+00H	worse		+18H	worse
	+18H	**better**	ϕ 400 hPa	+30H	worse
ϕ 850 hPa	+12H	worse	RH 400 hPa	+00H	worse
	+36H	worse	wind 400 hPa	+24H	worse

Table 1: List of parameters and forecast ranges where SE55 performs better/worse than REF2 in terms of RMSE scores against observation with significance 90 % two side confidence interval significance test.

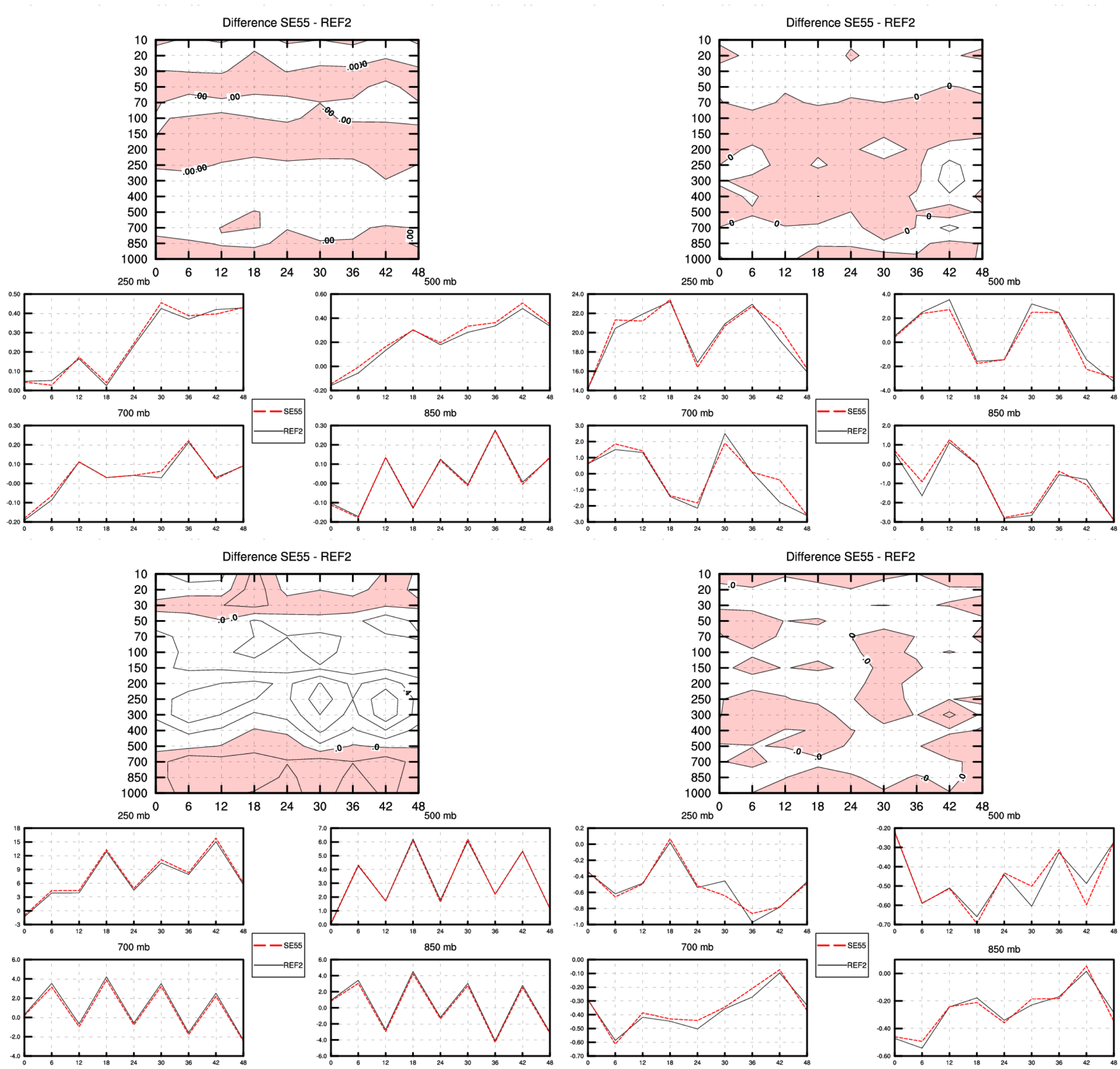

Fig. 5: BIAS for T (upper-left), RH (upper-right), ϕ (bottom-left) and wind speed (bottom-right) from 20060828 till 20060923 of 00 UTC runs. Red areas denote lower values in SE55 experiment.

SEVIRI data produces mostly cooling at mid-troposphere, drying between 700 and 100 hPa and lower values of geopotential up to 500 hPa.

Also in **comparison against ARPEGE analysis** there are not very big differences in the scores. The significantly negative impact is similarly for humidity on the surface and in upper troposphere (700 - 200 hPa). Next significant worsening was found in upper troposphere for geopotential, wind and temperature mostly for the analysis, but for humidity around 300 hPa there is negative impact up to 48H forecast range. Full list of of parameters and forecast ranges where SE55 performs better or worse than REF2 in terms of RMSE scores against ARPEGE analysis is in Table 2.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+00H	worse	T 300 hPa	+00H	worse
	+12H	worse	V 300 hPa	+12H	worse
T2m	+00H	worse	RH 300 hPa	+12H	worse
	+12H	worse		+24H	worse
RH 925 hPa	+00H	worse		+48H	worse
ϕ 500 hPa	+00H	worse	ϕ 250 hPa	+12H	worse
RH 500 hPa	+00H	worse	T 250 hPa	+00H	worse
wind 500 hPa	+00H	worse	RH 250 hPa	+00H	worse
	+12H	worse		+12H	worse
ϕ 300 hPa	+00H	worse		+24H	worse
	+12H	worse		+36H	worse
	+24H	worse		+48H	worse
RH 300 hPa	+00H	worse			

Table 2: List of parameters and forecast ranges where SE55 performs better/worse than REF2 in terms of RMSE scores against ARPEGE analysis with significance 90 % two side confidence interval significance test.

RMSE scores against ARPEGE analysis are on Fig. 6. Use of SEVIRI bring an improvement in lower troposphere around 925 hPa and 500 hPa for temperature, at 850 hPa for relative humidity, mostly up to 700 hPa for geopotential and wind speed.

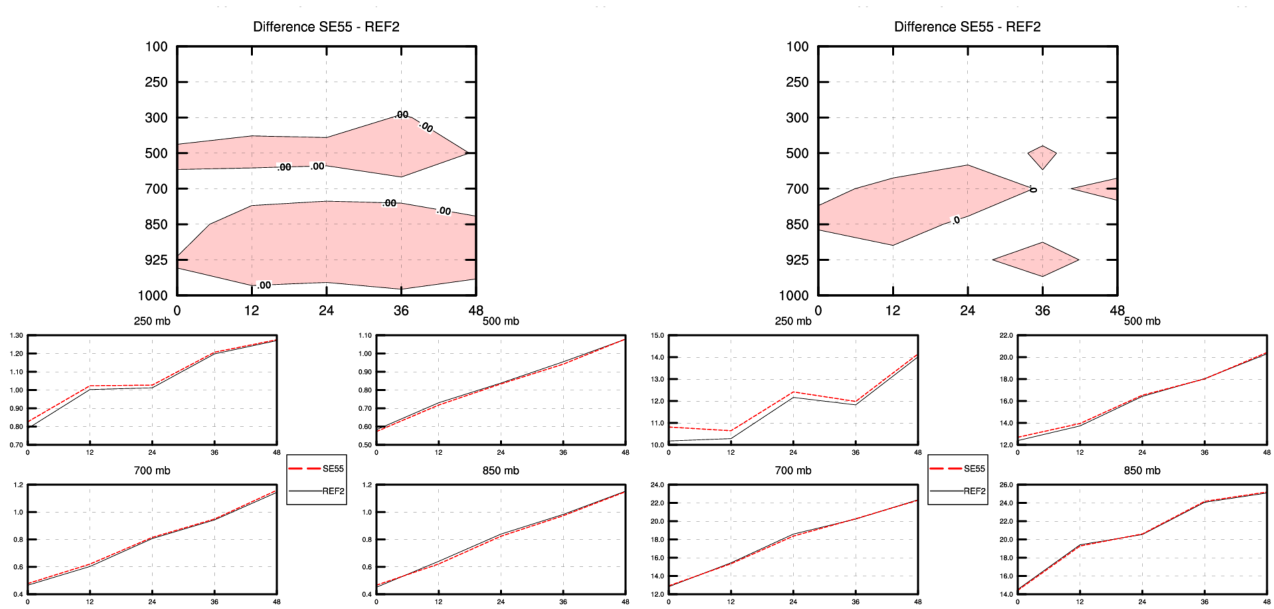

Fig. 6a: RMSE of T (left), RH (right) from 20060828 till 20060920 of 00 UTC runs. Red areas denote positive impact of SEVIRI usage against ARPEGE analysis.

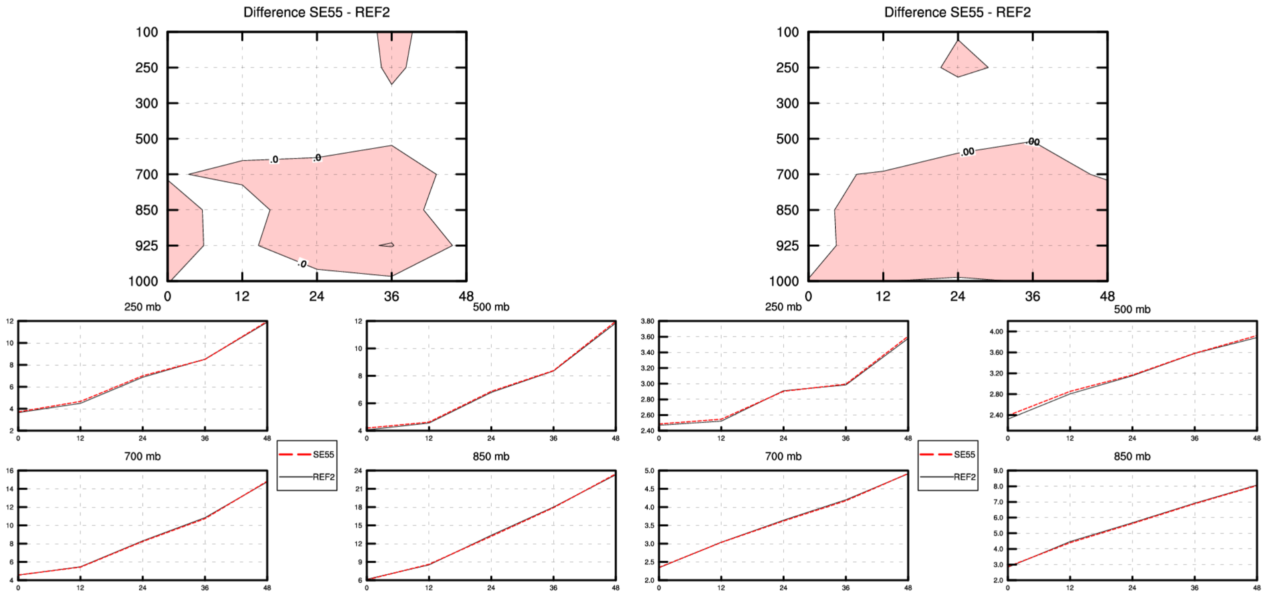

Fig. 6b: as Fig. 6a but for ϕ (left) and wind speed (right).

Conclusions

Verification against SYNOP and TEMP observations and also against ARPEGE analysis show very small differences in RMSE scores and significance test indicates significant impact of SEVIRI data, but dominantly negative.

3.2 Impact of using ensemble B matrix

In order to estimate the impact of ensemble B matrix an experiment **SE56** was performed and a new reference **REF3** was computed with ensemble B matrix and REDNMC=1. At first we present results without use of SEVIRI comparing **REF3** with **REF2** and then an impact of SEVIRI data with ensemble B matrix (**SE56** vs **REF3**) will be discussed.

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

3.2.1 Discussion and results without SEVIRI

Comparison against observations (REF3 vs REF2) didn't show unique positive or negative impact. The differences in RMSE scores (see Fig. 7) are small and the most apparent one is for geopotential. Red color indicate positive impact coming from use of ensemble B matrix.

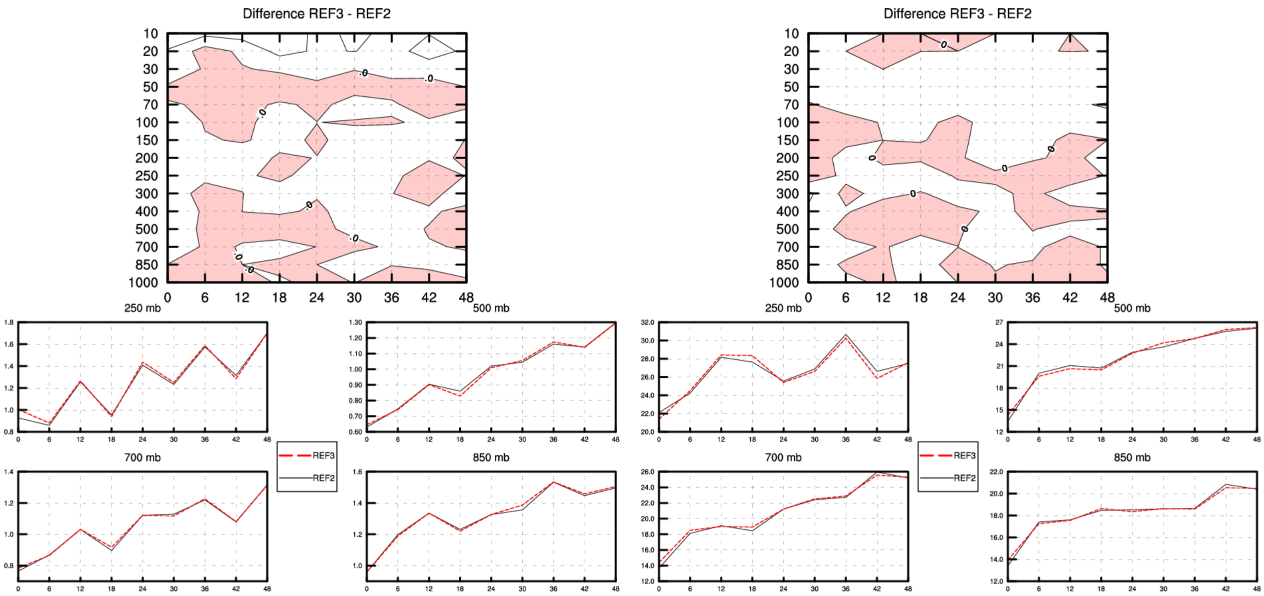

Fig. 7a: RMSE of T (left), RH (right) from 20060828 till 20060923 of 00 UTC runs.

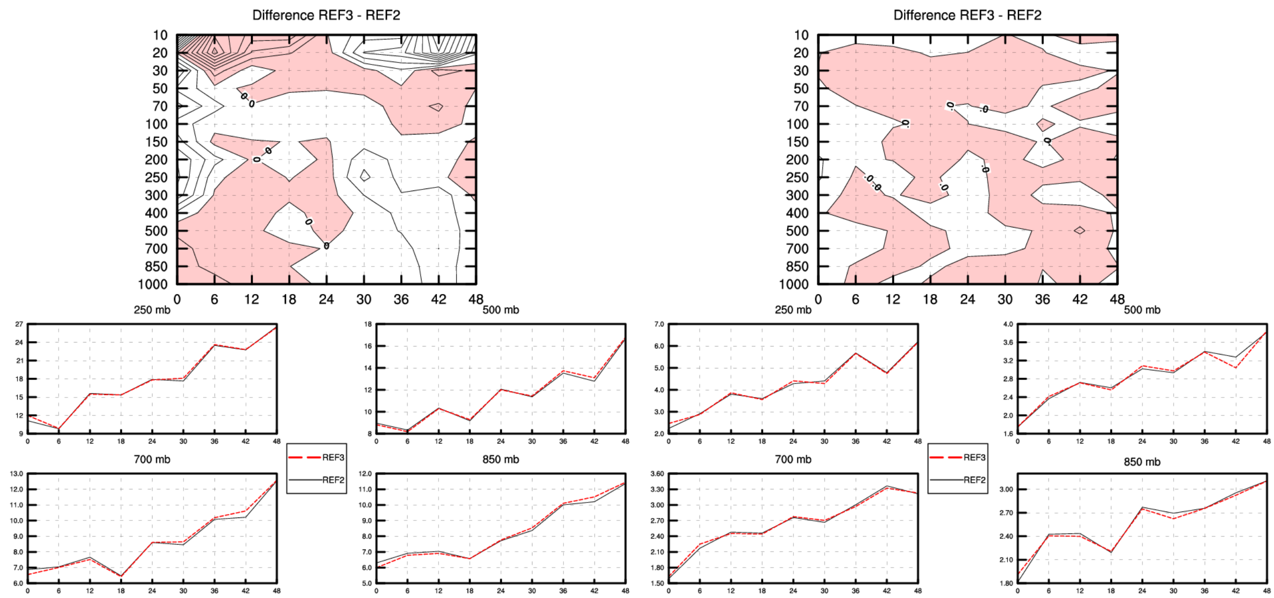

Fig. 7b: RMSE of ϕ (left) and wind speed (right) from 20060828 till 20060923 of 00 UTC runs.

But significance test pointed an improvement for geopotential in lower troposphere (up to 500 hPa) for the first 12H of forecast and significant degradation above for analysis. Also for temperature the negative impact on analysis from 700 to 200 hPa and for relative humidity from surface up to 300 hPa and at 200 hPa the positive impact was found significant. Full list of parameters and forecast ranges where REF3 performs better or worse than REF2 in terms of RMSE scores against observation is in Table 3. These results were a bit surprising. Previous tests (performed during different period and cycle CY28) had better scores (G. Boloni personal communication).

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

Table 3: List of parameters and forecast ranges where REF3 performs better/worse than REF2 in terms of RMSE scores against observation with significance 90 % two side confidence interval significance test.

Comparison against ARPEGE analysis (REF3 vs REF2) presented on Fig 8. show positive impact for all verified parameters for the first 12H at least. Significance test confirm the positive impact to be significant for all cases but one (ϕ at 700 hPa for +36H), complete list is summarized in following Table 4.

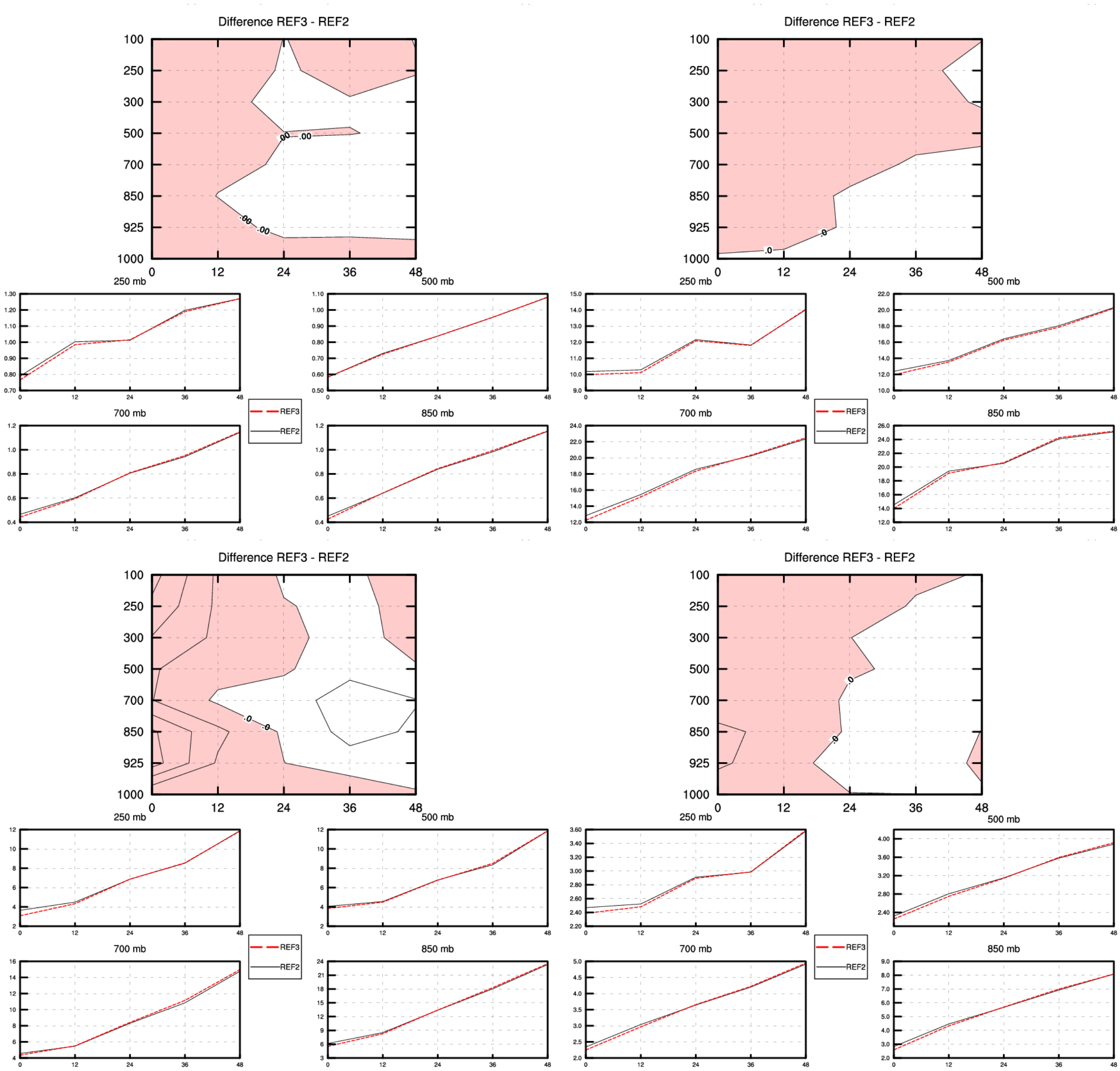

Fig. 8: RMSE of T (upper-left), RH (upper-right), ϕ (bottom-left) and wind speed (bottom-right) from 20060828 till 20060920 of 00 UTC runs. Red areas denote positive impact of SEVIRI usage against ARPEGE analysis.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+00H	**better**	T 700 hPa	+00H	**better**
	+12H	**better**	V 700 hPa	+00H	**better**
T2m	+00H	**better**		+12H	**better**
	+12H	**better**	RH 500 hPa	+00H	**better**
V10m	+00H	**better**		+12H	**better**
ϕ 1000 hPa	+12H	**better**		+36H	**better**
	+36H	**better**	V 500 hPa	+00H	**better**
T 1000 hPa	+00H	**better**		+12H	**better**

...

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
T 1000 hPa	+12H	**better**	ϕ 300 hPa	+00H	**better**
	+24H	**better**		+12H	**better**
	+36H	**better**	RH 300 hPa	+00H	**better**
V 1000 hPa	+00H	**better**		+12H	**better**
ϕ 925 hPa	+00H	**better**		+24H	**better**
T 925 hPa	+00H	**better**	T 300 hPa	+00H	**better**
	+12H	**better**	V 300 hPa	+00H	**better**
V 925 hPa	+00H	**better**		+12H	**better**
ϕ 850 hPa	+00H	**better**	ϕ 250 hPa	+00H	**better**
RH 850 hPa	+00H	**better**		+12H	**better**
	+12H	**better**	RH 250 hPa	+00H	**better**
T 850 hPa	+00H	**better**		+12H	**better**
V 850 hPa	+00H	**better**	T 250 hPa	+00H	**better**
ϕ 700 hPa	+00H	**better**		+12H	**better**
	+36H	worse	V 250 hPa	+00H	**better**
RH 700 hPa	+00H	**better**		+12H	**better**
	+12H	**better**			

Table 4: List of parameters and forecast ranges where REF3 performs better/worse than REF2 in terms of RMSE against ARPEGE analysis with significance 90 % two side confidence interval significance test.

These results are not contradicting previous comparison against TEMP observations what can be demonstrated on horizontal cross-section of RMSE differences against ARPEGE (Fig 9.), where the areas of the negative impact (in color) more or less coincide with location of TEMP stations (red triangles).

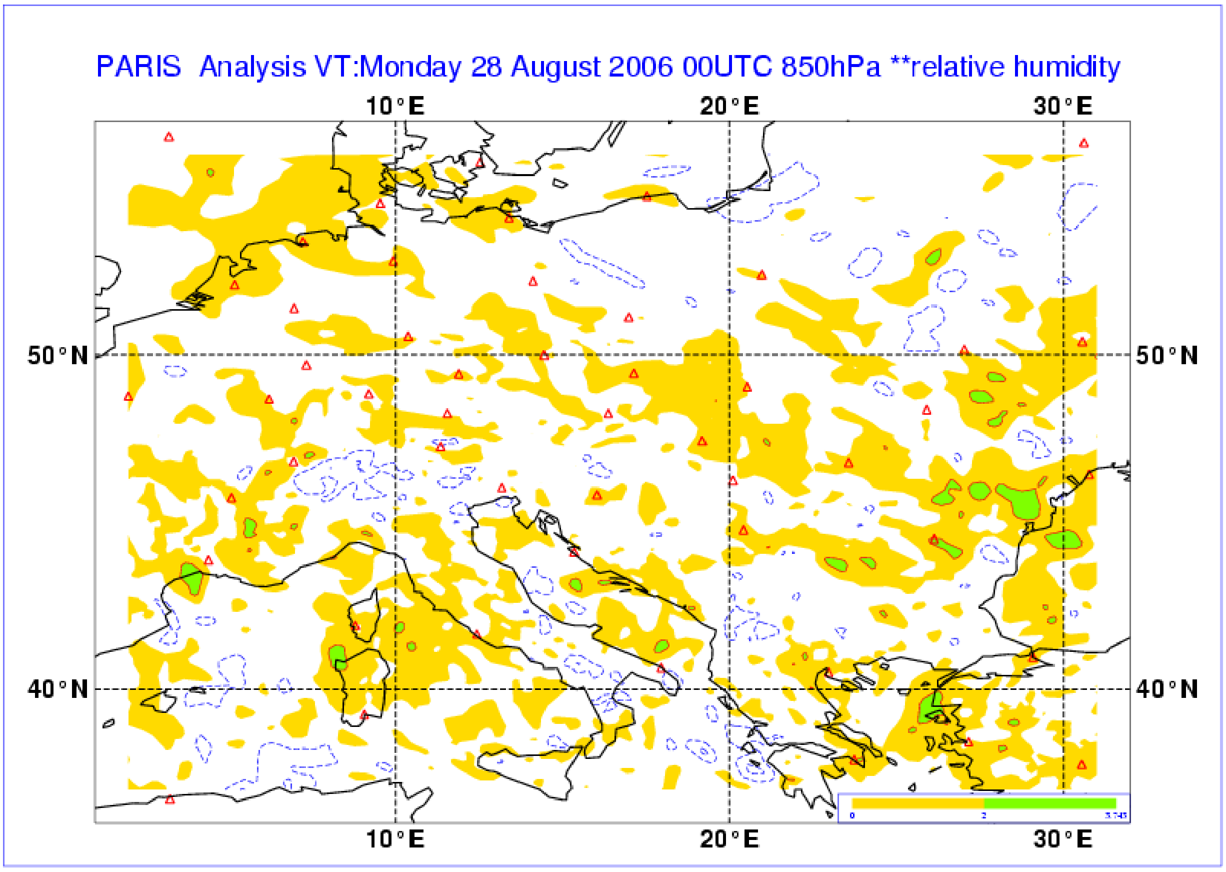

Fig. 9: Horizontal cross-section at 850 hPa of RMSE differences against analysis between experiment REF3 and REF2. Negative impact of REF3 is displayed in colors, positive with blue isolines and red triangles schematically shows the location of TEMP stations.

Conclusions: In despite of some degradation of scores against observation we decided to keep ensemble B matrix in further tuning experiments also because in the near future it will be used in operational in ALADIN/HU 3D VAR system.

3.2.2 Discussion and results with SEVIRI included

In order to reevaluate an impact of SEVIRI observation in system where ensemble B matrix is used we compared new reference **REF3** with **SE56** experiment.

Comparison against observations (SE56 vs REF3) showed again small differences in the RMSE scores, we can say that we have obtained more positive impact than in experiments using standard NMC (see Fig. 4 and Fig 10.). Also the significance test, compare Table 1. and Table 5., pointed less deficiencies, but they still prevail. And in terms of BIAS (see Fig. 11.) SEVIRI data produces mostly cooling at mid-troposphere and above 250 hPa, drying between 700 and 100 hPa and lower values of geopotential up to 500 hPa similarly as in case of using standard NMC B matrix.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+00H	worse	ϕ 700 hPa	+30H	**better**
	+18H	worse	RH 700 hPa	+42H	worse
V 10m	+48H	worse	V 700 hPa	+36H	worse
ϕ 1000 hPa	+12H	worse	RH 400 hPa	+24H	**better**
RH 1000 hPa	+00H	worse	V 300 hPa	+30H	**better**
ϕ 850 hPa	+12H	worse	RH 250 hPa	+30H	worse
RH 850 hPa	+24H	worse	V 250 hPa	+24H	**better**

Table 5: List of parameters and forecast ranges where SE56 performs better/worse than REF3 in terms of RMSE scores against observation with significance 90 % two side confidence interval significance test.

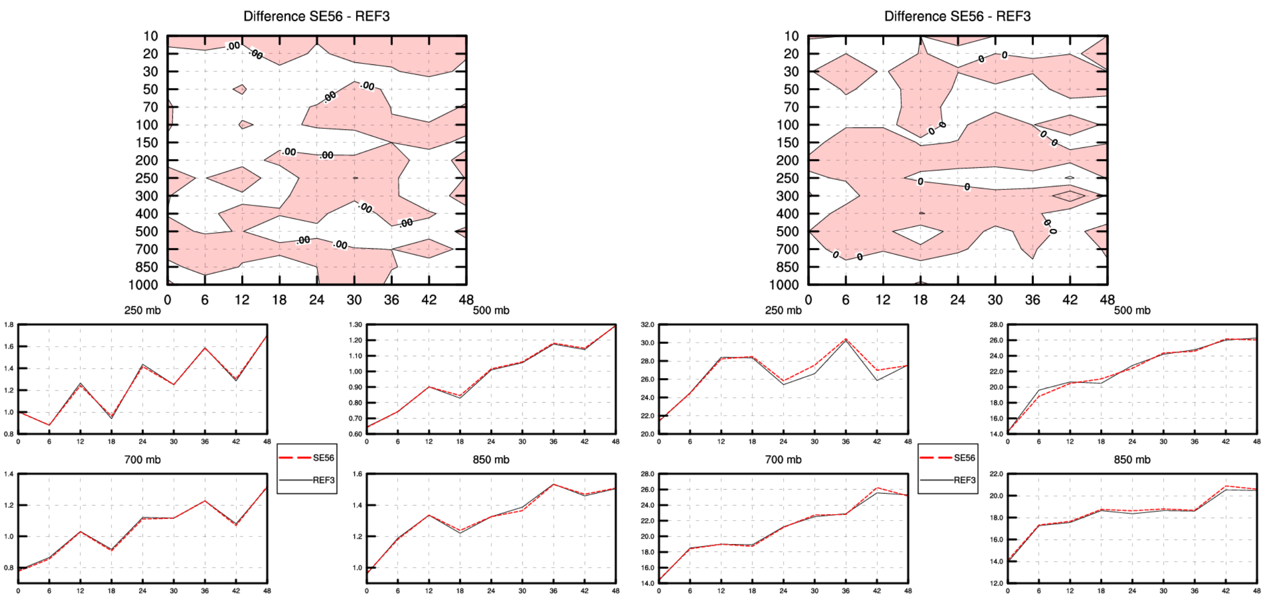

Fig. 10a: RMSE of T (left), RH (right) from 20060828 till 20060923 of 00 UTC runs. Red areas denote positive impact of SEVIRI.

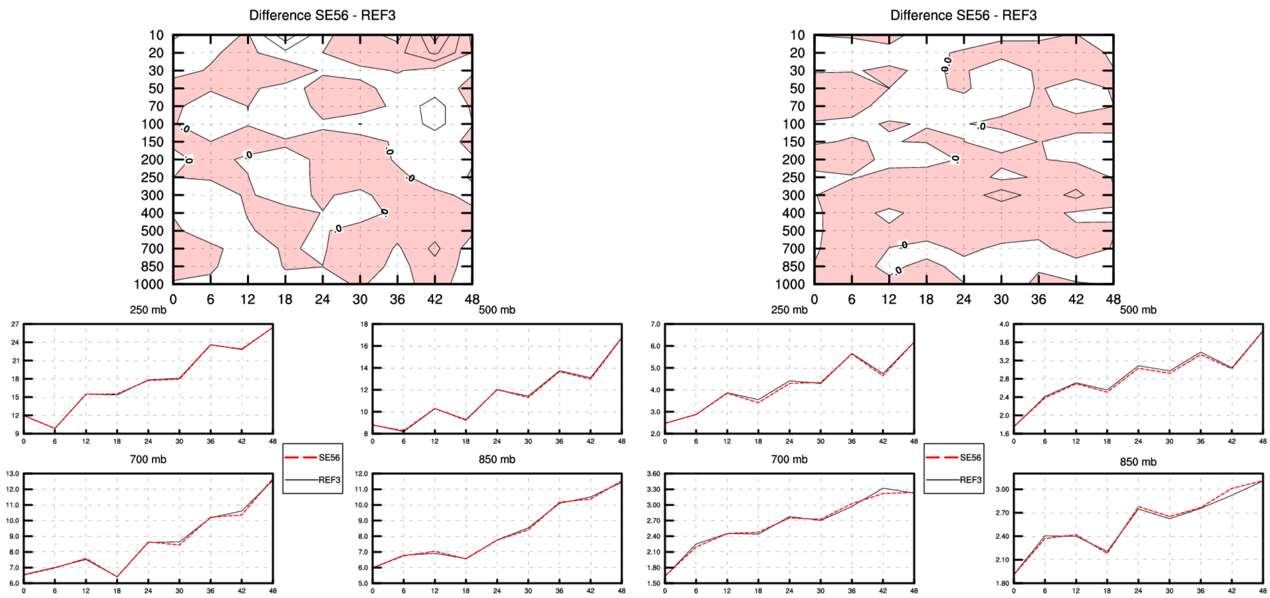

Fig. 10b: RMSE ϕ (left) and wind speed (right) from 20060828 till 20060923 of 00 UTC runs. Red areas denote positive impact of SEVIRI.

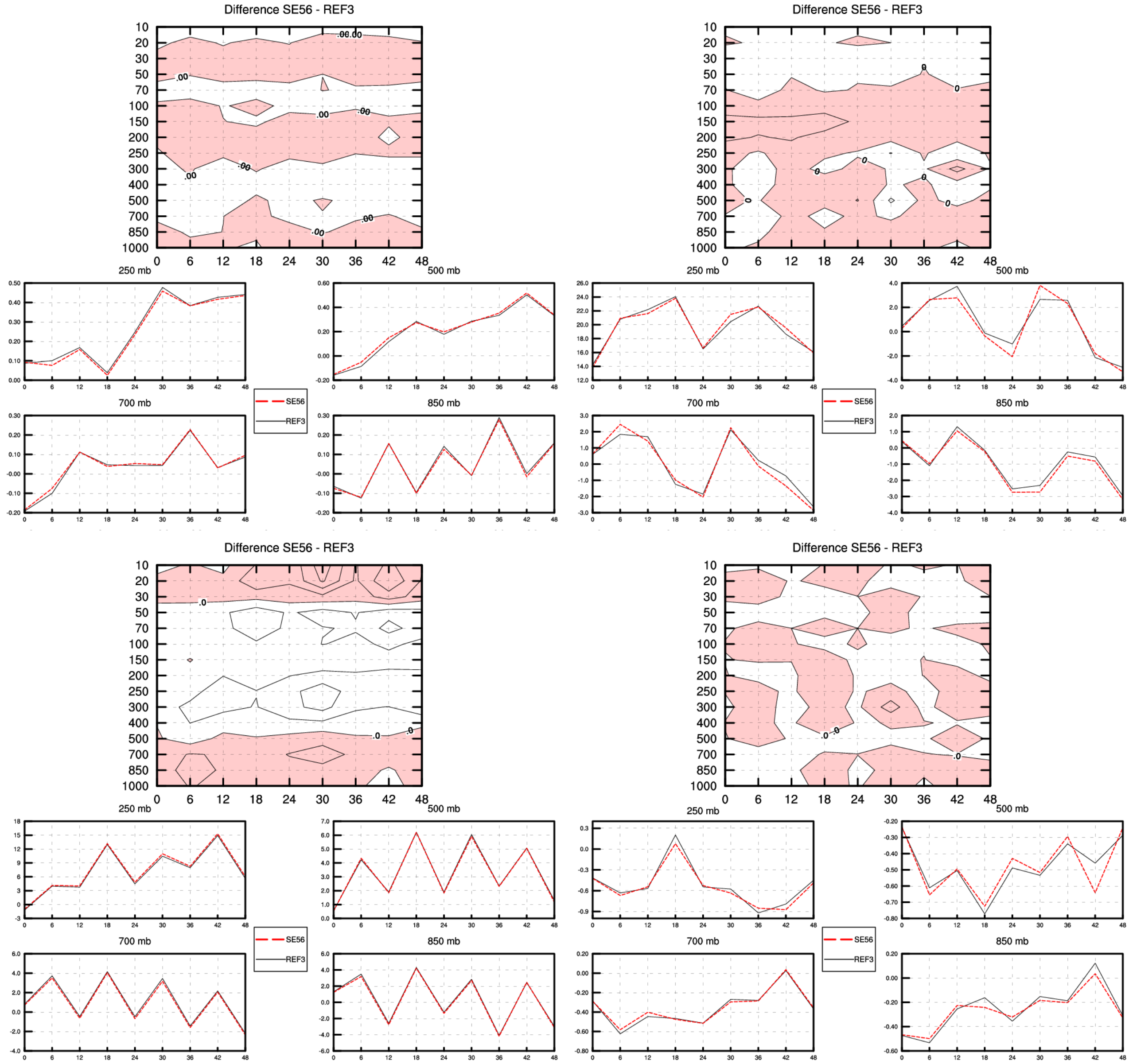

Fig. 11: BIAS for T (upper-left) and RH (upper-right), ϕ (bottom-left) and wind speed (bottom-right) from 20060828 till 20060923 of 00 UTC runs. Red areas denote lower values in SE56.

Comparison against ARPEGE analysis (SE56 vs REF3) RMSE scores against ARPEGE analysis are on Fig. 12 and Fig. 13. Use of SEVIRI bring an improvement in lower troposphere around 925 hPa and 500 hPa for temperature, between 925 and 500 hPa for relative humidity, mostly up to 700 hPa for geopotential and wind speed.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+00H	worse	T 500 hPa	+24H	**better**
T2m	+00H	worse	V 500 hPa	+00H	worse
ϕ 1000 hPa	+36H	worse	ϕ 300 hPa	+12H	worse
RH 1000 hPa	+00H	worse	RH 300 hPa	+00H	worse
	+12H	worse		+12H	worse
T 1000 hPa	+48H	worse		+24H	worse
RH 925 hPa	+24H	**better**	T 300 hPa	+00H	worse
V 850 hPa	+24H	**better**	ϕ 250 hPa	+12H	worse
	+36H	**better**	RH 250 hPa	+00H	worse
ϕ 700 hPa	+36H	**better**		+12H	worse
V 700 hPa	+00H	worse		+36H	worse
ϕ 500 hPa	+00H	worse		+48H	worse
T 500 hPa	+12H	**better**			

Table 6: List of parameters and forecast ranges where SE56 performs better/worse than REF3 in terms of RMSE scores against ARPEGE analysis with significance 90 % two side confidence interval significance test.

Results of significance test, compare Table 6 and Table 2, showed some positive impact, but there remain negative impact mostly at higher levels (300 and 250 hPa) and near surface. In terms of BIAS SEVIRI data produces mostly cooling at mid-troposphere, drying between 700 and 100 hPa and lower values of geopotential up to 500 hPa similarly as in case of using standard NMC B matrix.

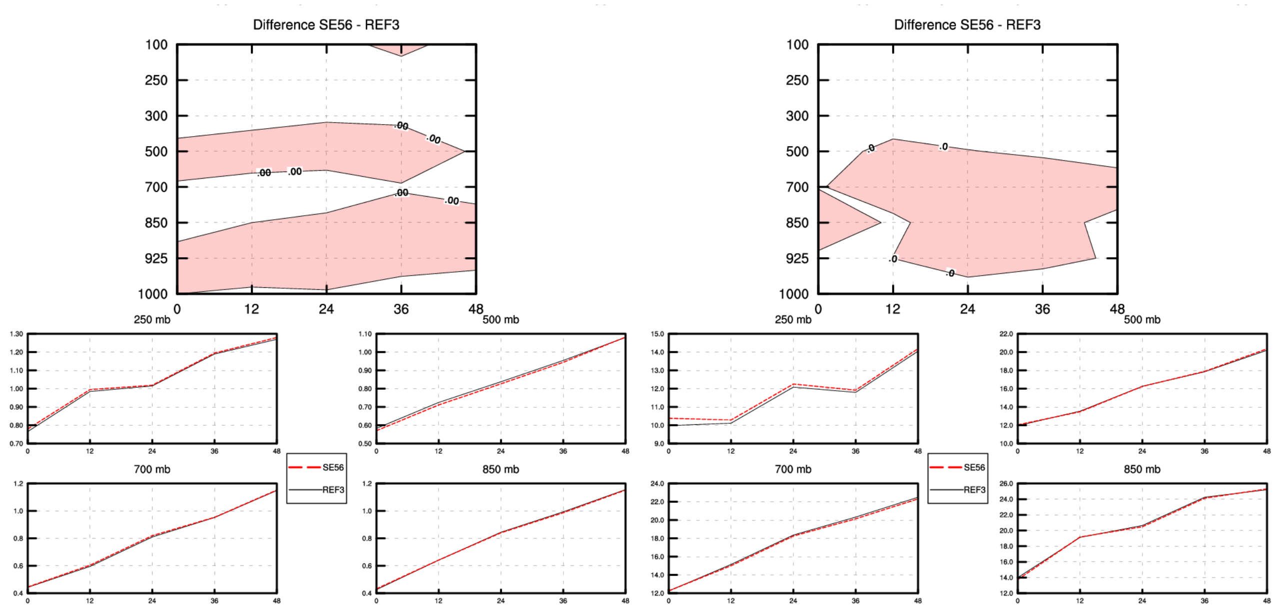

Fig. 12: RMSE of T (left), RH (right) for 00 UTC productions for period 20060828 till 20060920.
Red areas denote positive impact of SEVIRI usage against ARPEGE analysis.

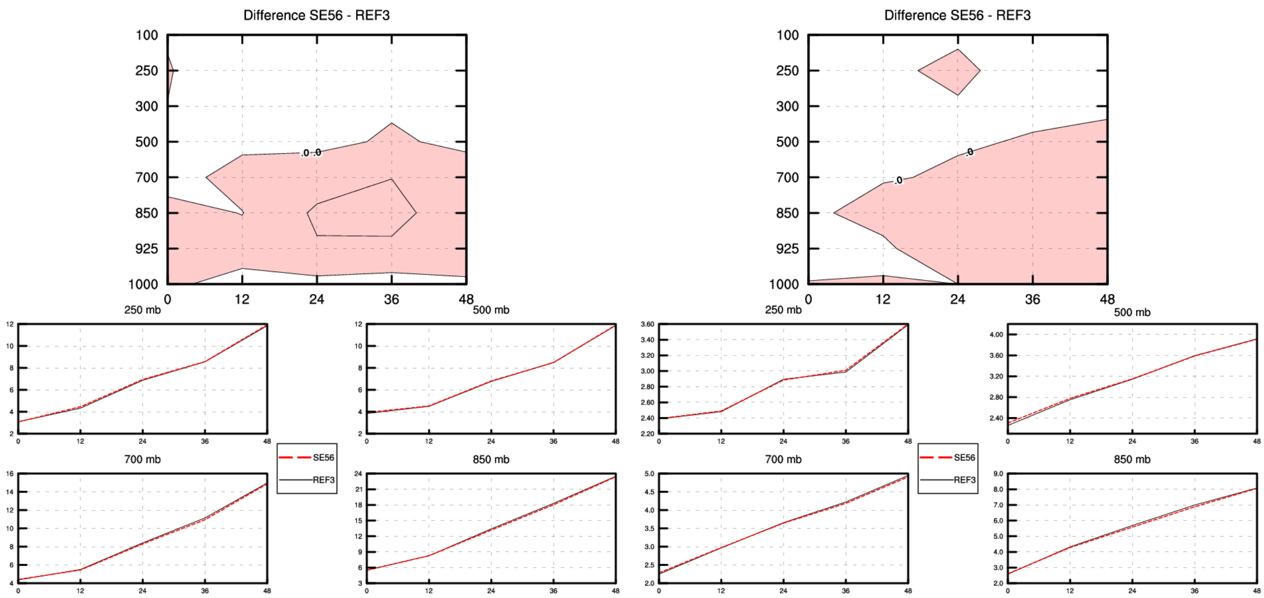

Fig. 13: RMSE of ϕ (left) and wind speed (right) for 00 UTC productions for period 20060828 till 20060920. Red areas denote positive impact of SEVIRI usage against ARPEGE analysis.

Conclusions: SEVIRI in the system using ensemble B matrix "performs better" than in the first test using standard NMC B matrix in terms of RMSE and also significance test pointed less deficiencies, but anyway they still prevail.

3.3 Impact of σ_o tuning for SEVIRI

As a next step we tried to tune observation errors of SEVIRI channels. Applying the diagnostic method of Desroziers *et al.*, it seemed that we should decrease σ_o for all channels about 50%. And to see also impact of increasing of σ_o too, we performed following two experiments:

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

3.3.1 Discussion and results

Comparison against observations for reference **REF3**, **SE56** with default setting of σ_o and above mentioned experiments **SE57** and **SE58** at chosen levels are on Fig. 14-Fig. 16.

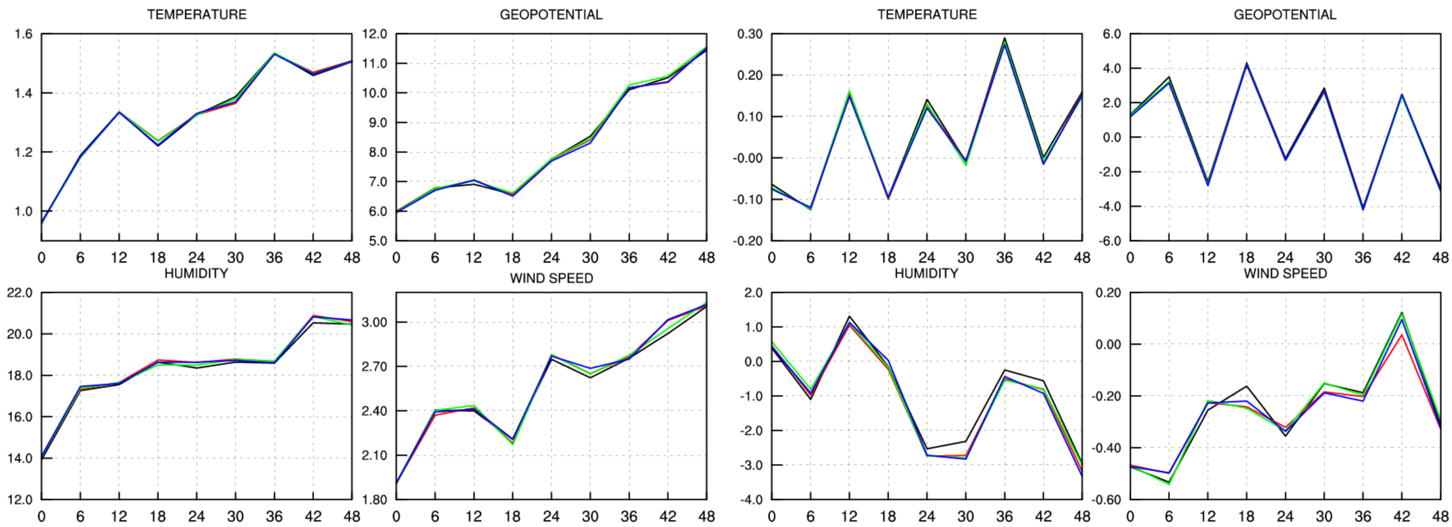

Fig. 14: RMSE against observation (left) and BIAS (right) for 850 hPa level from 20060828 till 20060923 of 00 UTC runs. Experiment REF3 is in black, SE56 in red, SE57 in green and SE58 in blue.

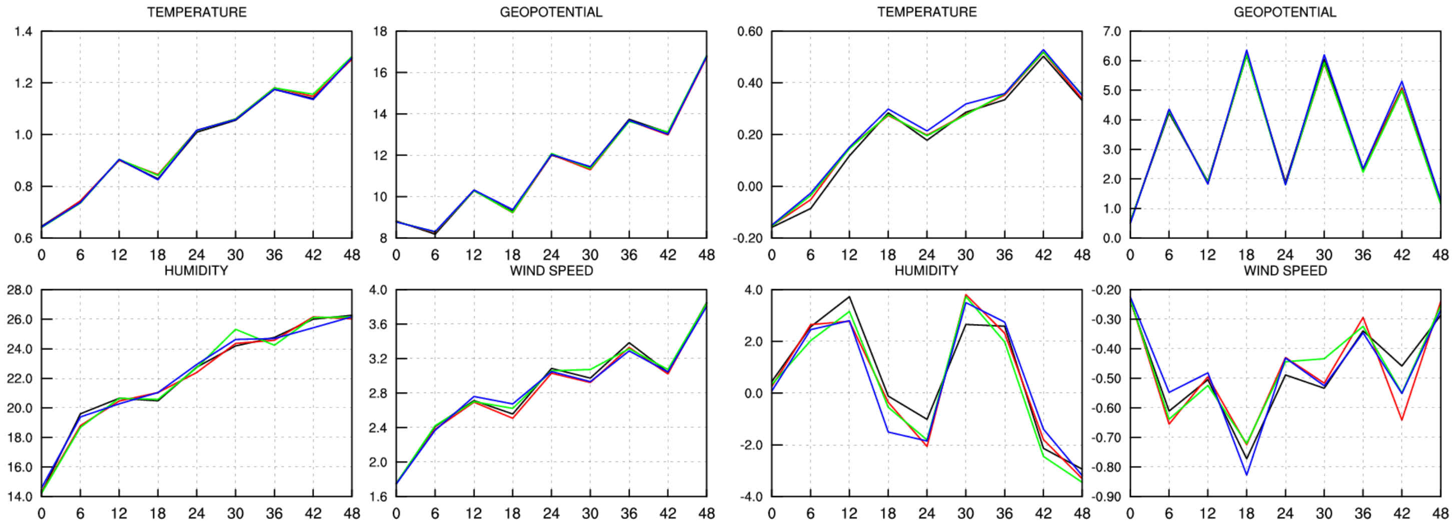

Fig. 15: RMSE against observation (left) and BIAS (right) for 500 hPa level from 20060828 till 20060923 of 00 UTC runs. Experiment REF3 is in black, SE56 in red, SE57 in green and SE58 in blue.

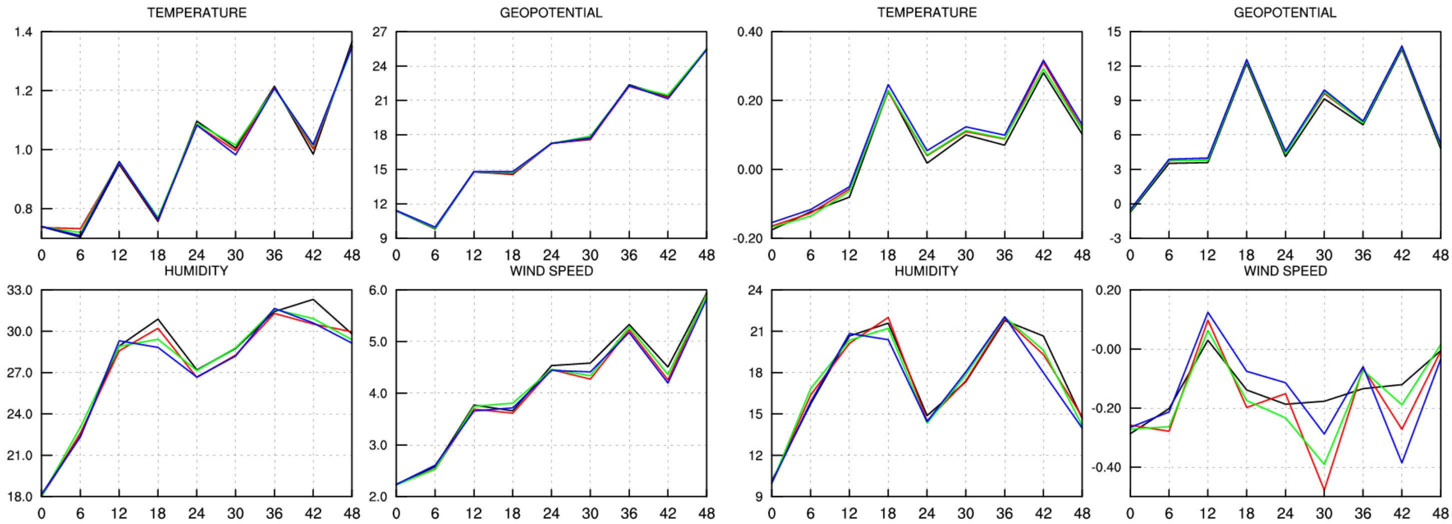

Fig. 16: As Fig. 15 but for 300 hPa.

There is no evident unique improvement nor degradation in the impact of modified σ_o for SEVIRI channels. Only results of significance test could help to evaluate an impact of **SE56**, **SE57** and **SE58**, see Table 6, Table 7 and Table 8. And SEVIRI with σ_o decreased by 40% has the best scores of significance test with respect to **REF3**.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
ϕ 1000 hPa	+36H	worse	ϕ 700 hPa	+48H	worse
	+48H	worse	RH 700 hPa	+42H	worse
ϕ 850 hPa	+36H	worse	V 700 hPa	+00H	worse
	+48H	worse	RH 500 hPa	+36H	**better**
RH 850 hPa	+00H	worse	T 400 hPa	+30H	worse
ϕ 700 hPa	+30H	**better**	T 250 hPa	+12H	worse

Table 7: List of parameters and forecast ranges where SE57 performs better/worse than REF3 in terms of RMSE scores against observation with significance 90 % two side confidence interval significance test.

There are not big differences in **comparison against ARPEGE analysis** with 40% observation error increase or decrease for SEVIRI channels. To review the experiments **SE57** and **SE58**, the RMSE scores are shown on Fig. 17 - Fig. 20 and the corresponding significance test on Table 9 and Table 10. Run with SEVIRI data using σ_o increased by 40% has better scores in terms of significance test against **REF3**.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
ϕ 1000 hPa	+12H	worse	ϕ 400 hPa	+06H	worse
ϕ 850 hPa	+12H	worse	RH 400 hPa	+00H	worse
	+30H	**better**	V 300 hPa	+12H	**better**
RH 850 hPa	+00H	worse		+30H	**better**
	+24H	worse	T 250 hPa	+12H	**better**
ϕ 700 hPa	+30H	**better**		+24H	**better**
			V 250 hPa	+24H	**better**

Table 8: List of parameters and forecast ranges where SE58 performs better/worse than REF3 in terms of RMSE scores against observation with significance 90 % two side confidence interval significance test.

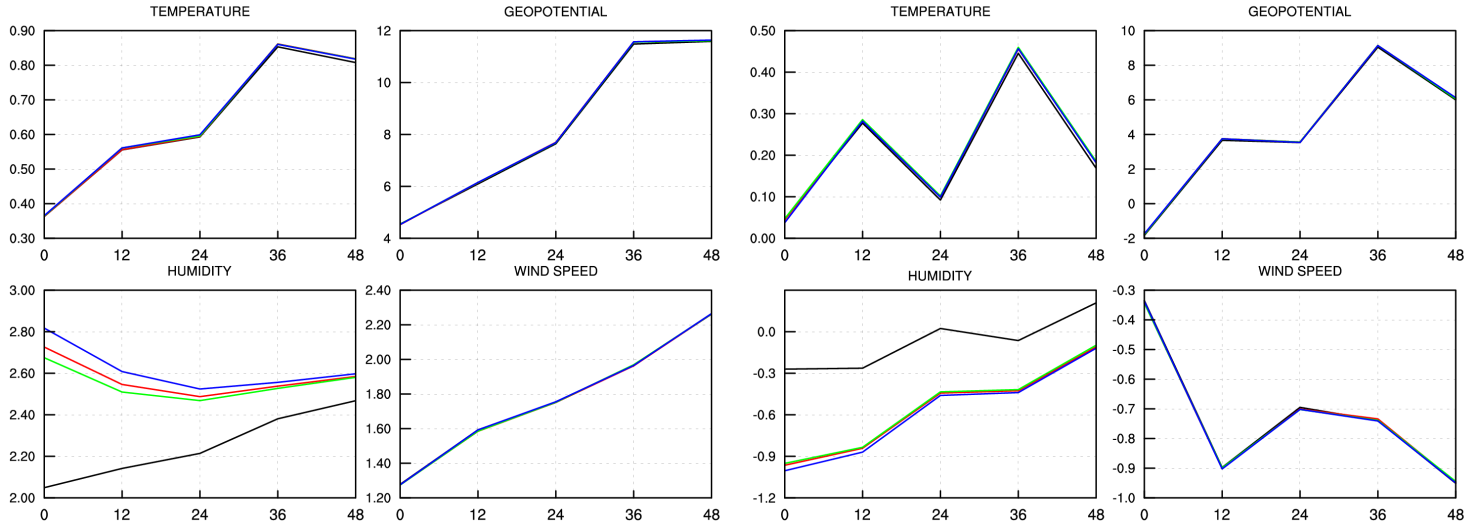

Fig. 17: Verification against ARPEGE analysis. RMSE (left) and BIAS (right) for 1000 hPa level for all ranges of 00 UTC productions for period from 20060828 till 20060920. Experiment REF3 is in black, SE56 in red, SE57 in green and SE58 in blue.

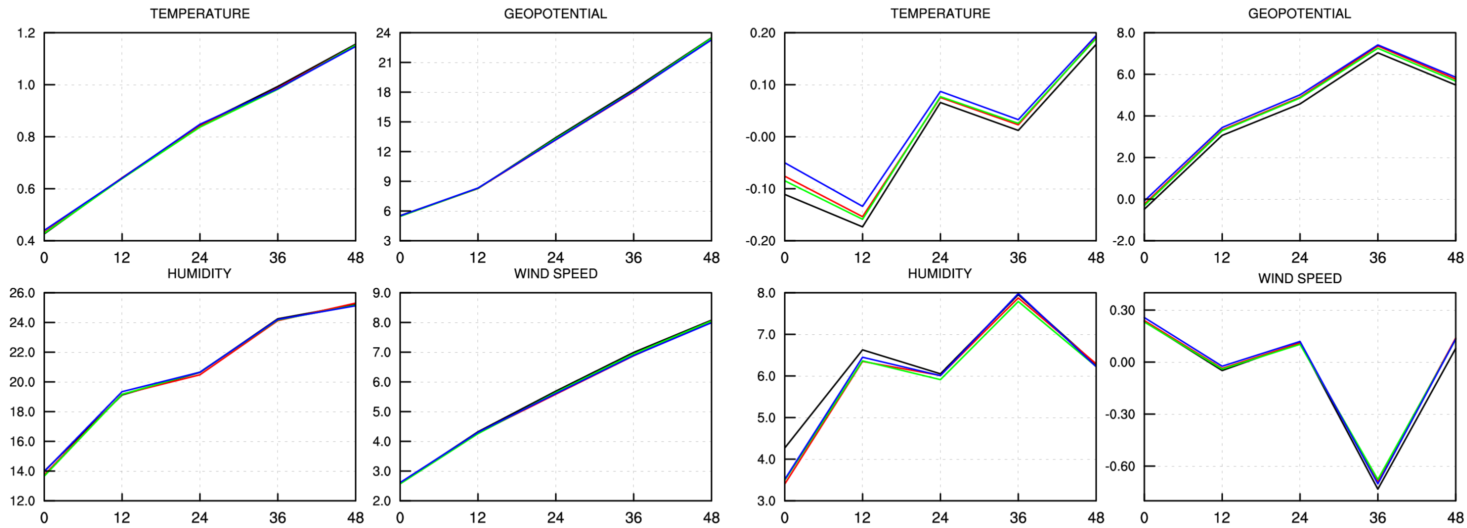

Fig. 18: Verification against ARPEGE analysis. RMSE (left) and BIAS (right) for 850 hPa level for all ranges of 00 UTC productions for period from 20060828 till 20060920. Experiment REF3 is in black, SE56 in red, SE57 in green and SE58 in blue.

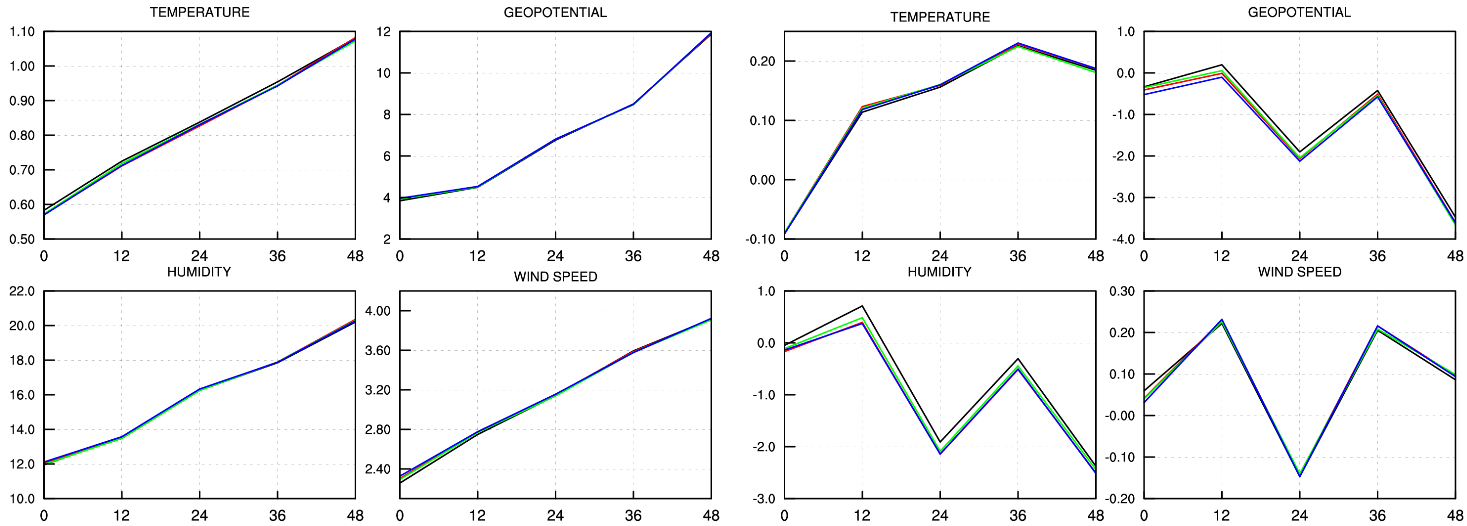

Fig. 19: Verification against observation. RMSE (up) and BIAS (down) for 500 hPa level for all ranges of 00 UTC productions for period from 20060828 till 20060923. Experiment REF3 is in black, SE56 in red, SE57 in green and SE58 in blue.

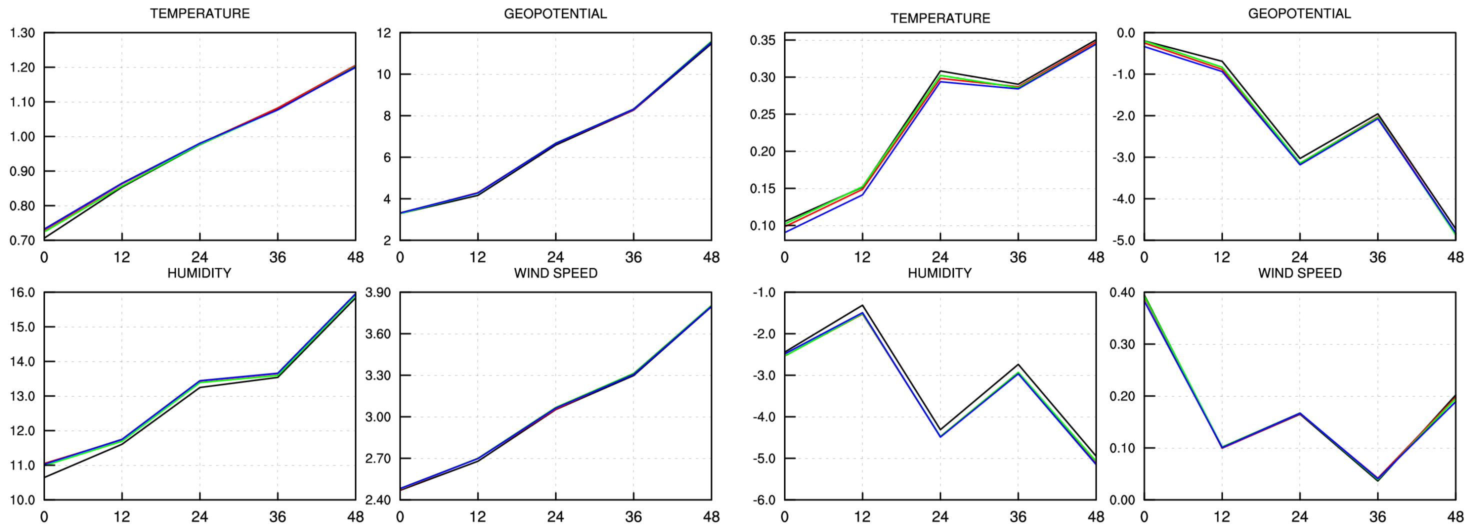

Fig. 20: Verification against observation. RMSE (up) and BIAS (down) for 300 hPa level for all ranges of 00 UTC productions for period from 20060828 till 20060923. Experiment REF3 is in black, SE56 in red, SE57 in green and SE58 in blue.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+00H	worse	V 500 hPa	+00H	worse
RH 1000 hPa	+00H	worse	ϕ 300 hPa	+12H	worse
	+12H	worse	RH 300 hPa	+00H	worse
V 925 hPa	+24H	**better**		+24H	worse
ϕ 850 hPa	+00H	**better**	T 300 hPa	+00H	worse
RH 850 hPa	+00H	**better**	ϕ 250 hPa	+12H	worse
ϕ 700 hPa	+36H	**better**	RH 250 hPa	+00H	worse
ϕ 500 hPa	+00H	worse		+12H	worse

Table 9: List of parameters and forecast ranges where SE57 performs better/worse than REF3 in terms of RMSE scores against ARPEGE analysis with significance 90 % two side confidence interval significance test.

Conclusions: By tuning of σ_o we have not obtained any clear guideline. The differences in the scores are very small and it is very difficult to judge impact. One reason can be that 40% σ_o modification were too small and thus also the impact was small. Or that our data assimilation system is too much driven by some other observation types and that is why we can not get bigger impact, to check this idea we performed last set of experiments.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+00H	worse	V 700 hPa	+00H	worse
T2m	+00H	worse		+48H	**better**
ϕ 1000 hPa	+36H	worse	ϕ 500 hPa	+00H	worse
RH 1000 hPa	+00H	worse	V 500 hPa	+00H	worse
	+12H	worse	RH 300 hPa	+00H	worse
	+24H	worse		+12H	worse
	+36H	worse		+24H	worse
	+48H	worse		+36H	worse
ϕ 850 hPa	+48H	**better**		+48H	worse
V 850 hPa	+36H	**better**	T 300 hPa	+00H	worse
ϕ 700 hPa	+00H	worse	RH 250 hPa	+00H	worse
	+36H	**better**		+12H	worse
RH 700 hPa	+00H	worse		+24H	worse
	+36H	**better**		+36H	worse
	+48H	**better**		+48H	worse
T 700 hPa	+12H	worse			

Table 10: List of parameters and forecast ranges where SE58 performs better/worse than REF3 in terms of RMSE scores against ARPEGE analysis with significance 90 % two side confidence interval significance test.

3.4 Impact of SEVIRI data on the top of SYNOP and TEMP observation only

To evaluate the impact of SEVIRI data on less complex assimilation system (with regard to use of different observation types) we computed new reference **REF4** with only SYNOP and TEMP observations included in 3D VAR and experiment **SE50** with SYNOP, TEMP and SEVIRI data included.

- **REF4** - SYNOP, TEMP observations with ensemble B matrix
- **SE50** - REF4 + SEVIRI (with default σ_o)

3.4.1 Discussion and results

Comparison against observation (SE50 vs REF4) is displayed on Fig 21 - Fig. 22. Differences in RMSE are small.

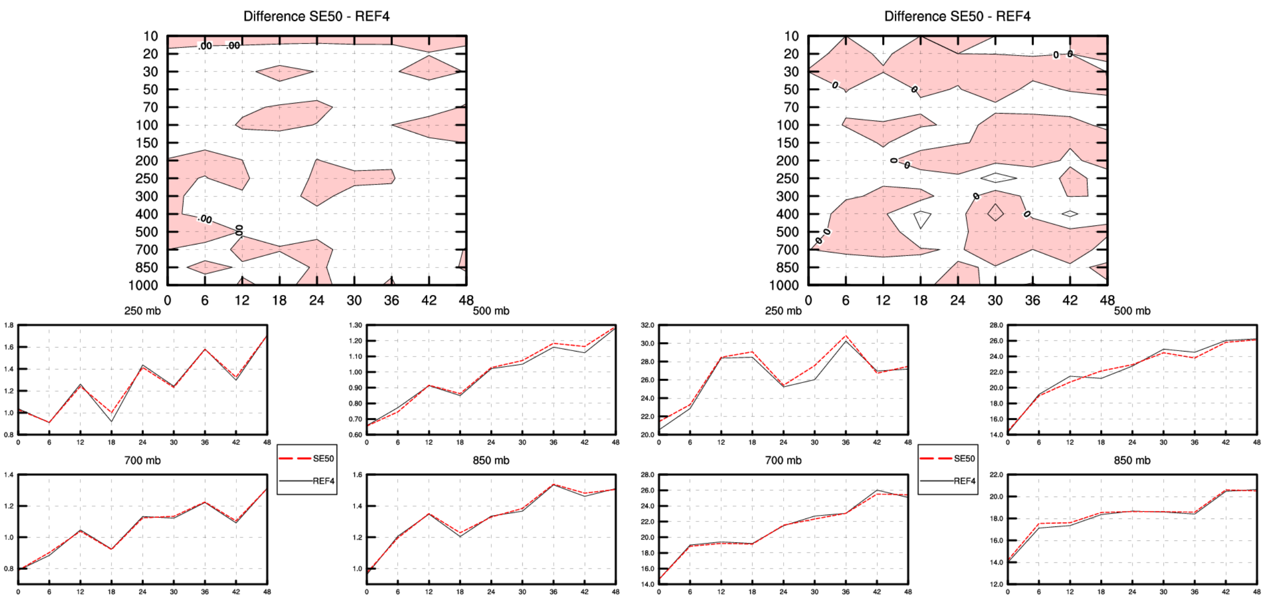

Fig. 21a: RMSE against observation of T (left), RH (right) from 20060828 till 20060923 of 00 UTC runs.

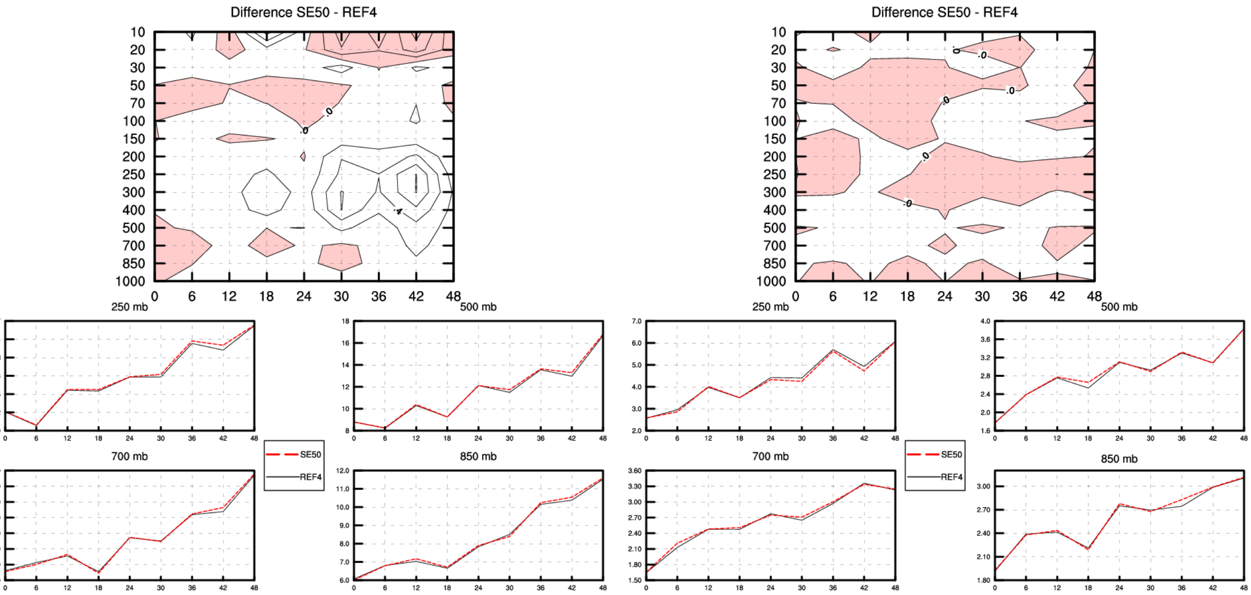

Fig. 21b: RMSE against observation of ϕ (left) and wind speed (right) from 20060828 till 20060923 of 00 UTC runs.

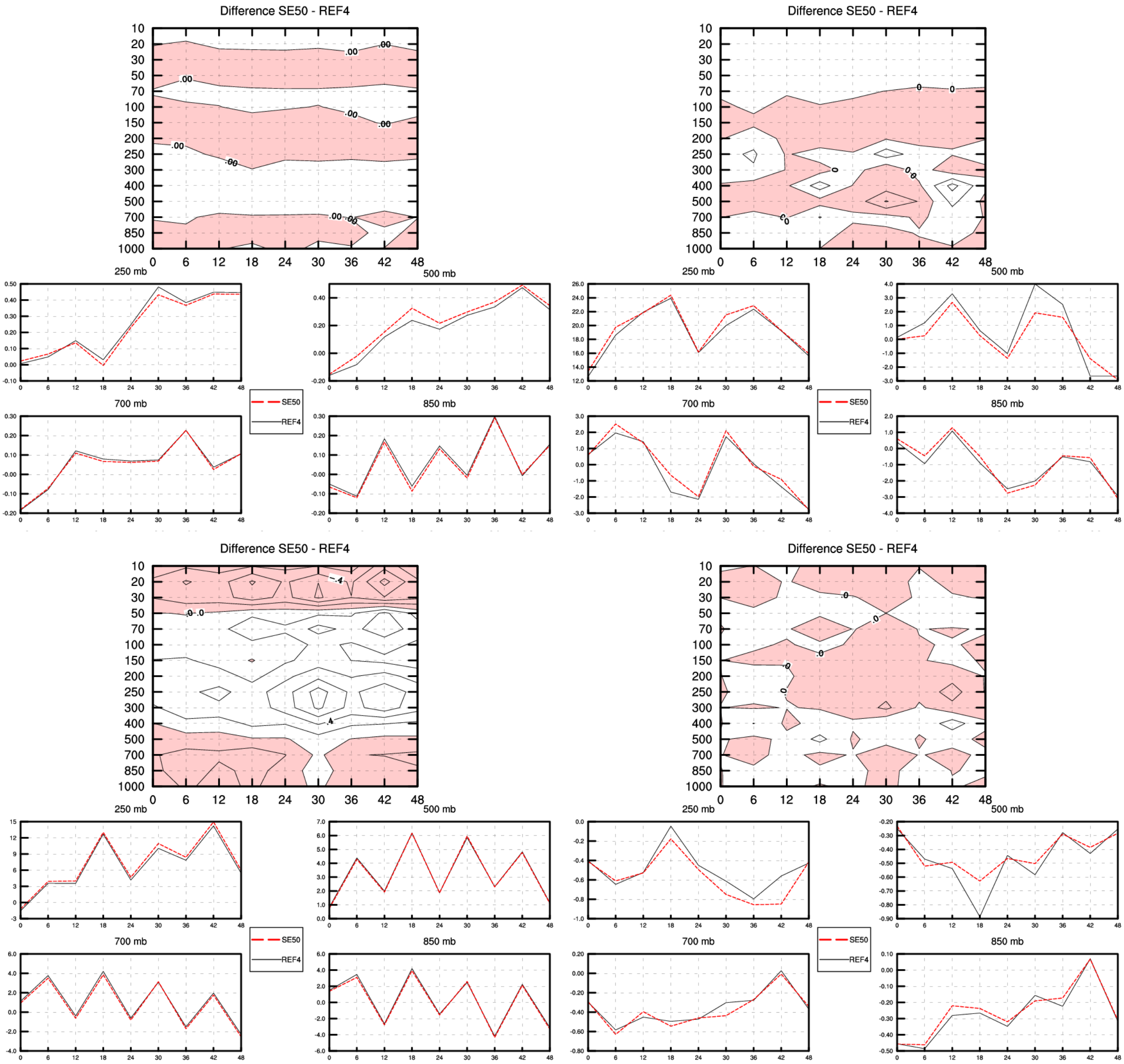

Fig. 22: BIAS of temperature (upper-left), RH (upper-right), ϕ (bottom-left) and wind speed (bottom-right) for 00 UTC productions for period 20060828 till 20060923.

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

Table 11: List of parameters and forecast ranges where SE50 performs better/worse than REF4 in terms of RMSE scores against observation with significance 90 % two side confidence interval significance test.

Concerning BIAS SEVIRI data produces mostly cooling at mid-troposphere (up to 700 hPa) and above 200 hPa, drying around 500 and 150 hPa and lower values of geopotential up to 500 hPa similarly as before. Table 11 summarizes the results of significance test, where prevail worse performance of SEVIRI experiment.

And also we can evaluate **SE50** and **REF3** with respect to **REF4** to compare the impact of SEVIRI with the remaining observations (ATOVS, AMDAR and AMV) used on the top of SYNOP and TEMP. As can be seen on Fig. 23 and Fig. 24 the impact is more noticeable for ATOVS, AMDAR and AMV data, but an extent of RMSE differences is quite the same as for SEVIRI. Concerning BIAS, impact on temperature is quite the same, for relative humidity brings more drying around 500 hPa and 150 hPa.

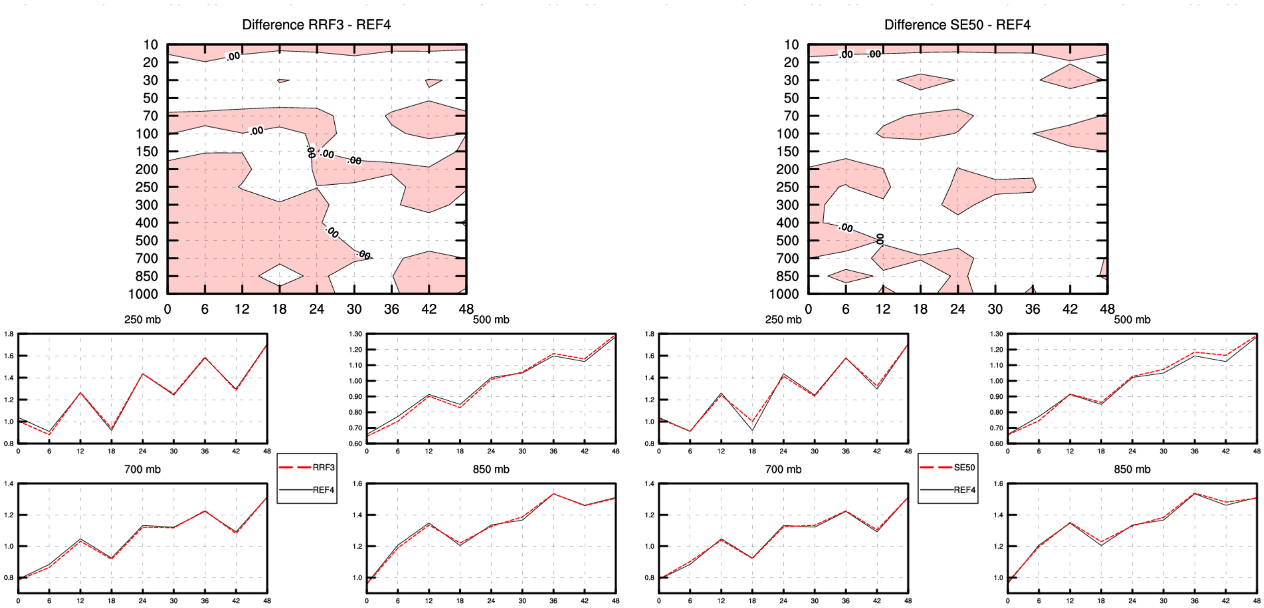

Fig. 23a: RMSE of T against observation due to ATOVS, AMDAR and AMV on the left and SEVIRI on the right, RRF3 stands for REF3 (due to visualization problem) for 00 UTC productions for period 20060828 till 20060923.

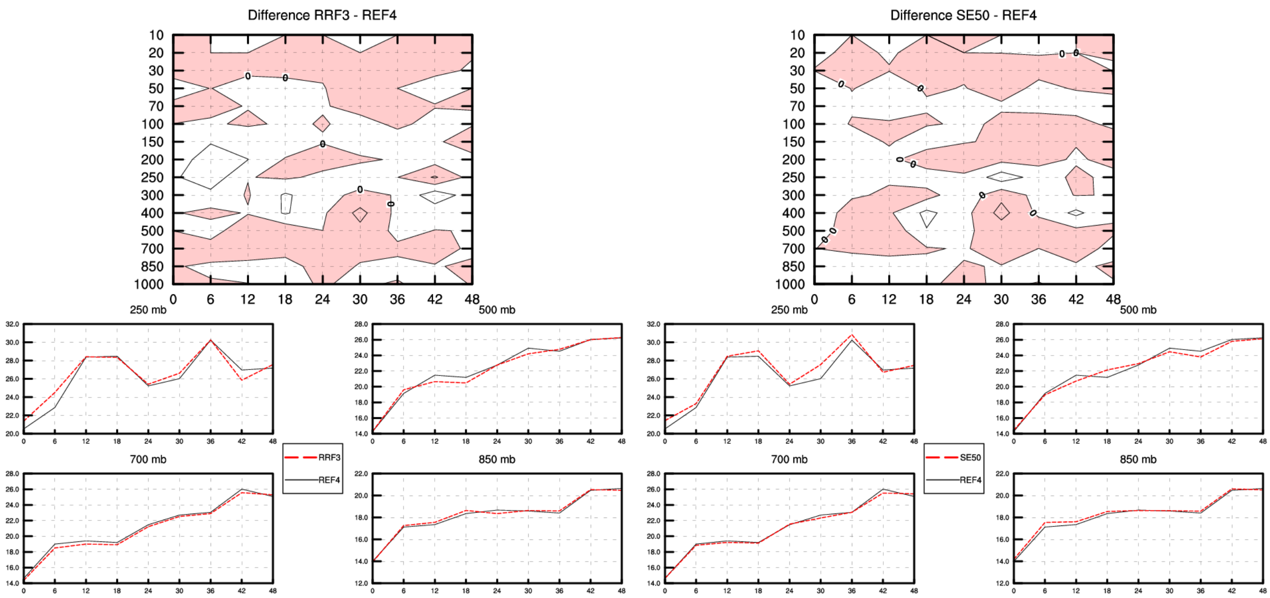

Fig. 23b: as Fig. 23a, but for RH

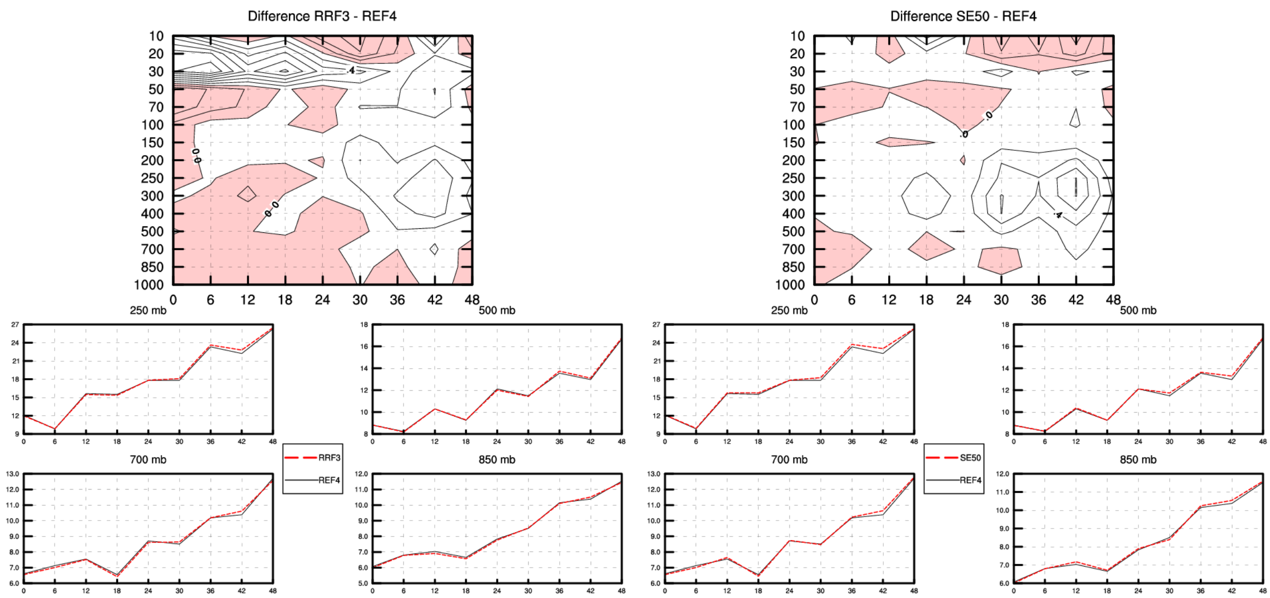

Fig. 23c: as Fig. 23a, but for ϕ

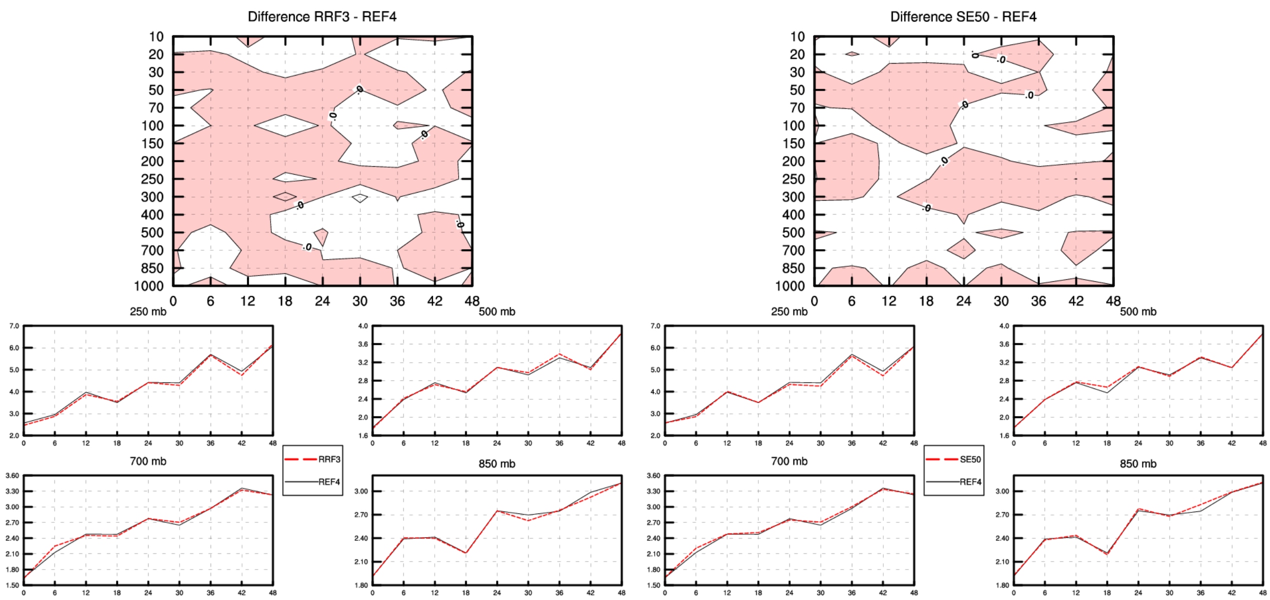

Fig. 23d: as Fig. 23a, but for wind speed

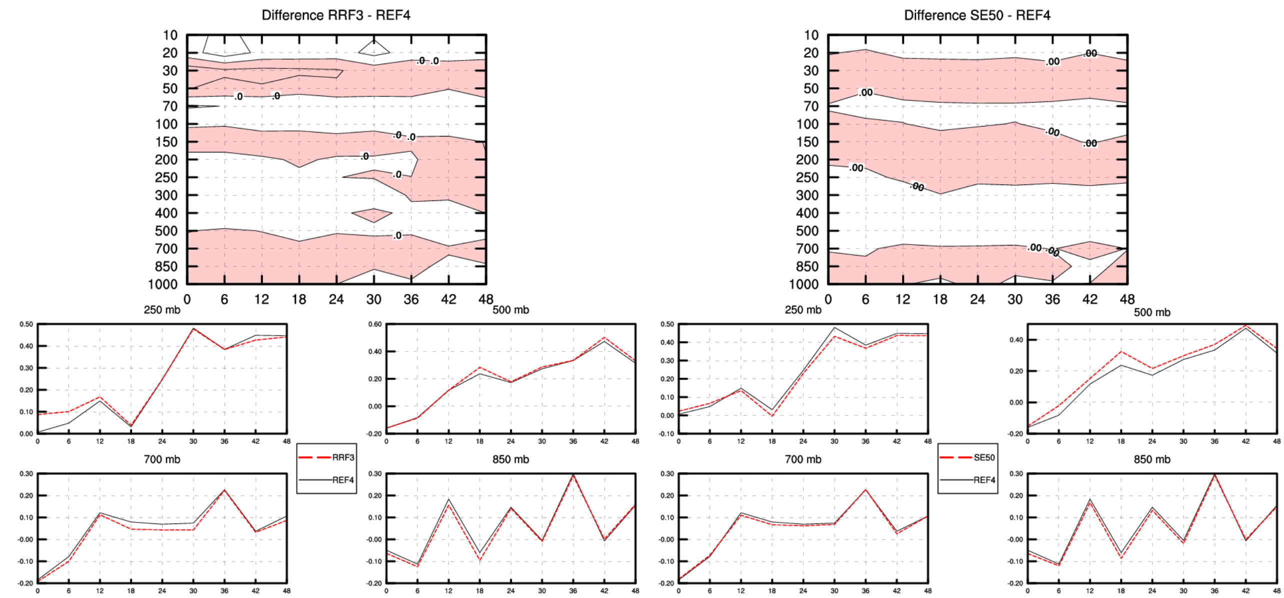

Fig. 25a: BIAS of T against observation due to ATOVS, AMDAR and AMV on the left and SEVIRI on the right for 00 UTC productions for period 20060828 till 20060923.

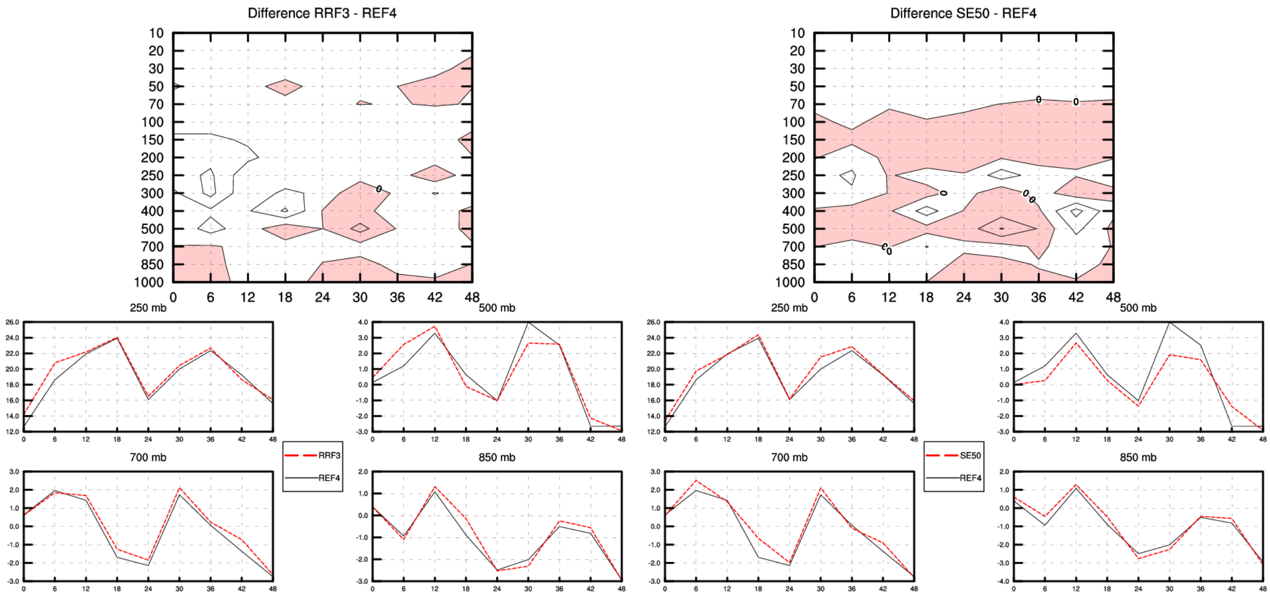

Fig. 24b: as Fig. 24a, but for RH

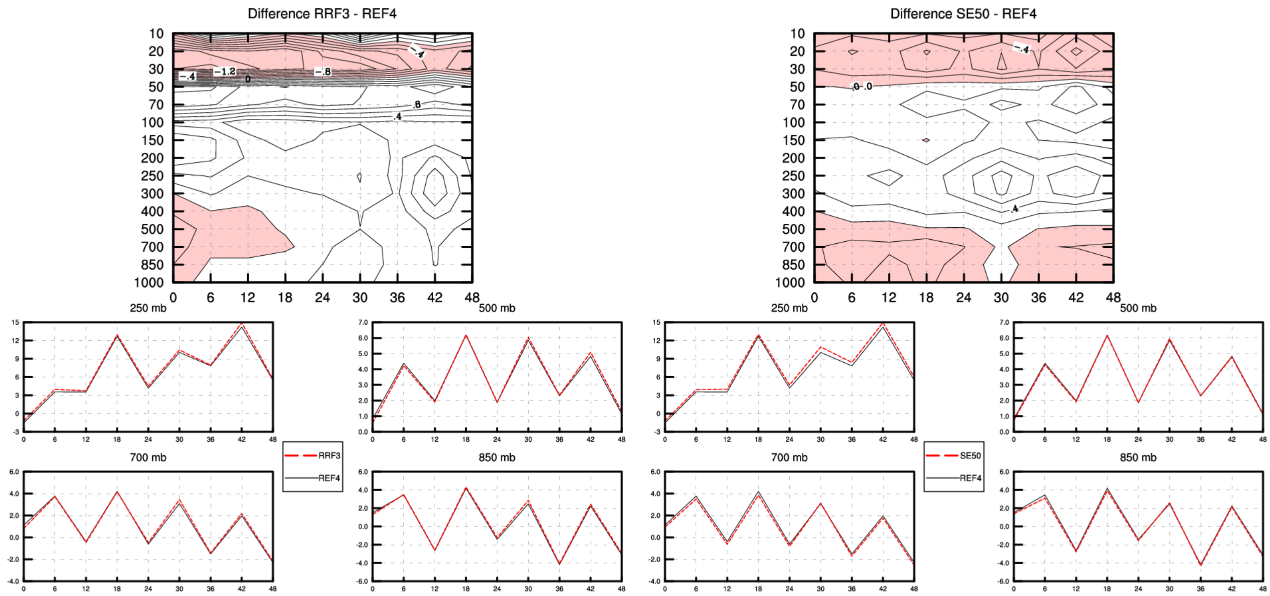

Fig. 24c: as Fig. 24a, but for ϕ

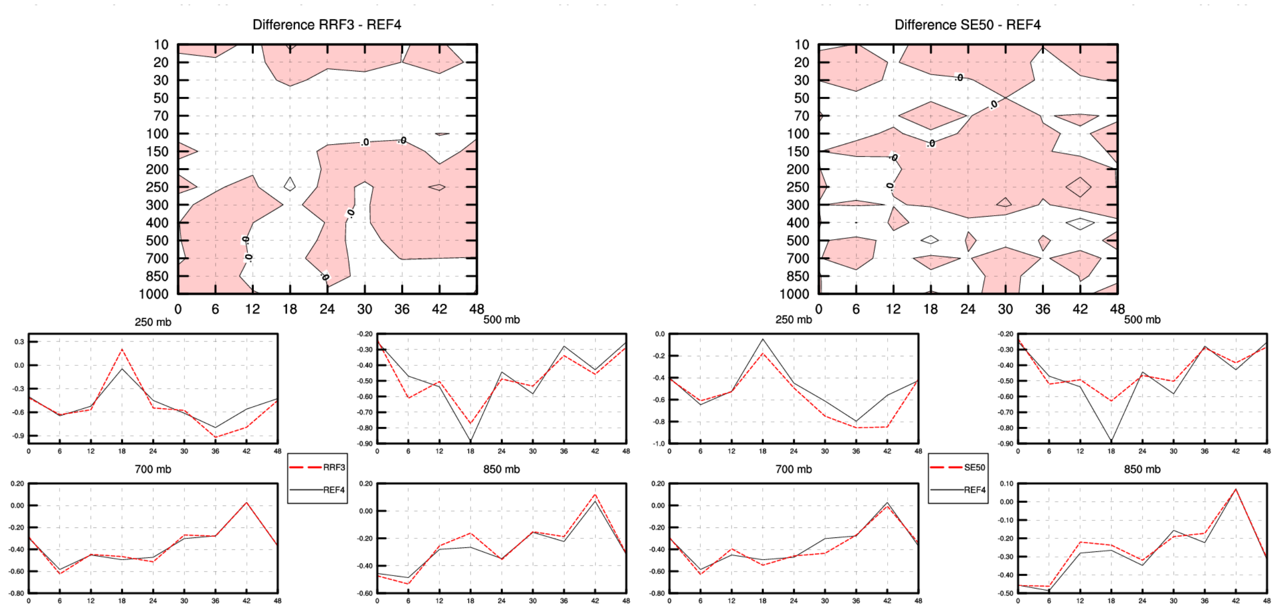

Fig. 24d: as Fig. 24a, but for wind speed

Also in the **comparison against ARPEGE analysis (SE50 vs REF4)** on Fig. 25 - Fig. 27. there are small differences in RMSE. Very little improvement was found in BIAS for relative humidity between 850 and 500 hPa, around 925 and 500 for temperature, for geopotential and wind speed mostly in mid-troposphere.

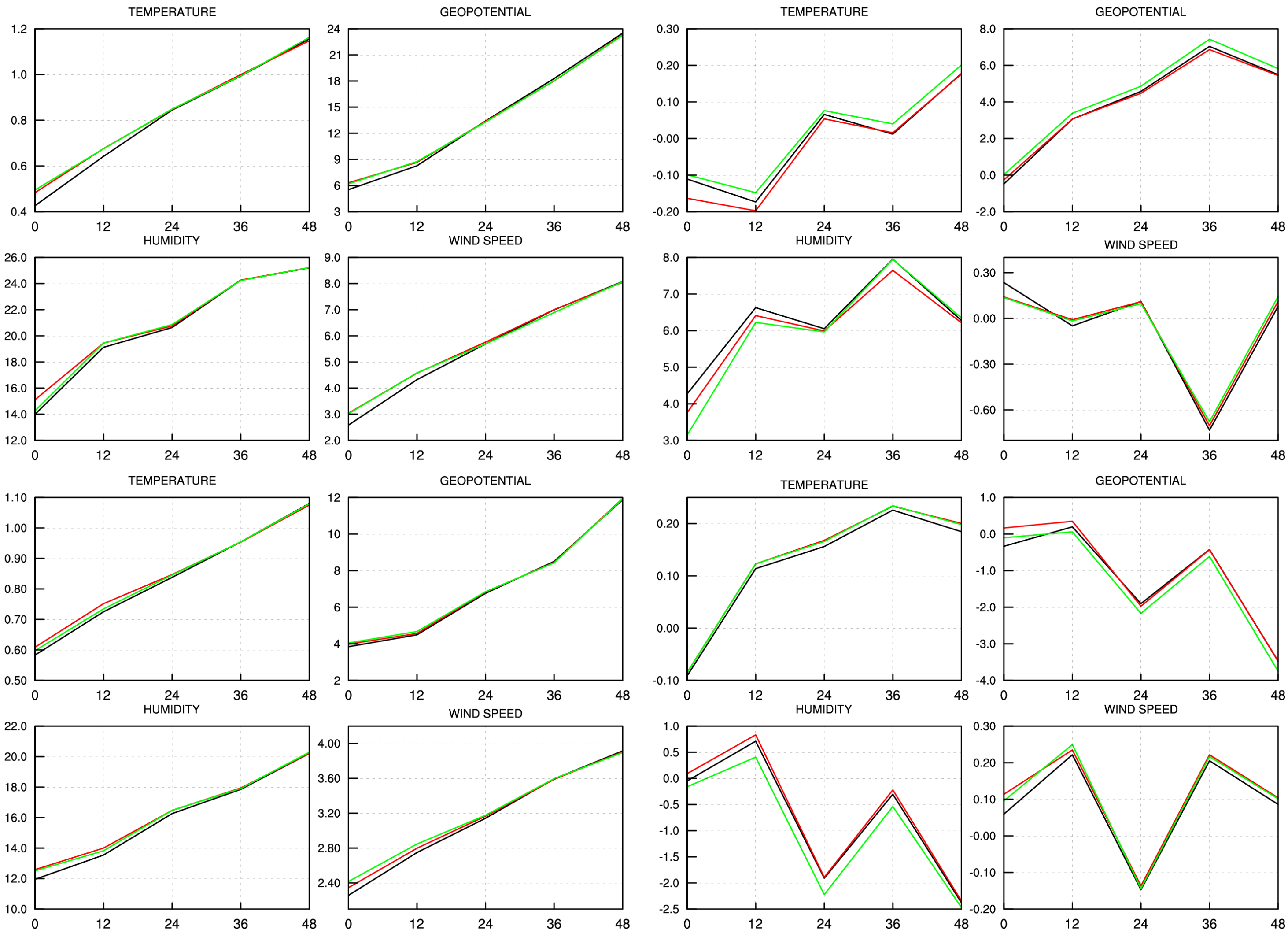

Fig. 25: RMSE against ARPEGE analysis (left) and BIAS (right) for 850 hPa level (up) and for 500 hPa (down) from 20060828 till 20060920 of 00 UTC runs. Experiment REF3 is in black, REF4 in red and SE50 in green.

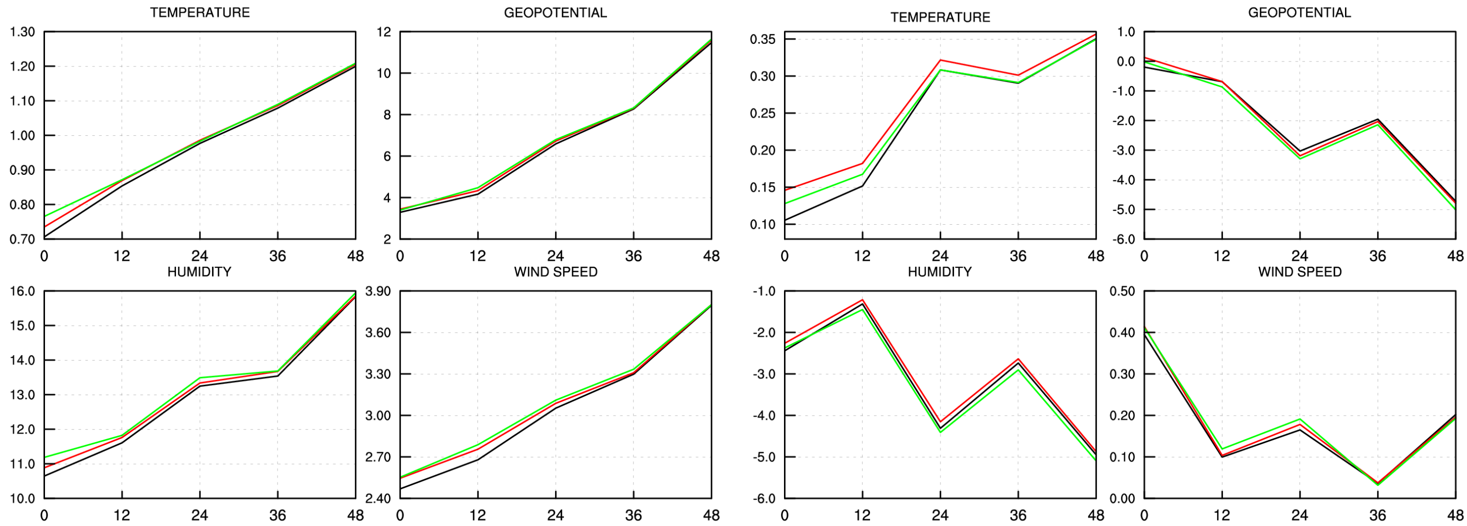

Fig. 27: RMSE against ARPEGE analysis (left) and BIAS (right) for 300 hPa from 20060828 till 20060920 of 00 UTC runs. Experiment REF3 is in black, REF4 in red and SE50 in green.

Parameter	Forecast	Significance at 90%	Parameter	Forecast	Significance at 90%
RH2m	+00H	worse	V 500 hPa	+00H	worse
	+48H	worse		+12H	worse
T2m	+00H	worse	RH 300 hPa	+00H	worse
RH 1000 hPa	+00H	worse		+24H	worse
	+12H	worse	T 300 hPa	+00H	worse
	+24H	worse	V 300 hPa	+12H	worse
T 925 hPa	+00H	**better**	RH 250 hPa	+00H	worse
RH 850 hPa	+00H	**better**		+12H	worse
V 850 hPa	+36H	**better**		+24H	worse
RH 700 hPa	+00H	**better**		+36H	worse
	+12H	**better**		+48H	worse
T 500 hPa	+12H	**better**	T 250 hPa	+00H	worse
			V 250 hPa	+12H	worse

Table 12: List of parameters and forecast ranges where SE50 performs better/worse than REF4 in terms of RMSE scores against ARPEGE analysis with significance 90 % two side confidence interval significance test.

Conclusions: An impact of SEVIRI data on less complex assimilation system (using SYNOP and TEMP observations only) is small, thus an idea that the system is too much driven by ATOVS, AMDAR and AMV observations was not confirmed. An extent of RMSE differences is quite the same as for SEVIRI and remaining observations. From last comparison against dynamical adaptation presented on following figures Fig.28 to Fig. 29, can be deduced that most of the information is coming from TEMP observation or the verification against observation (the same TEMP observation as assimilated) is kind of 'biased'.

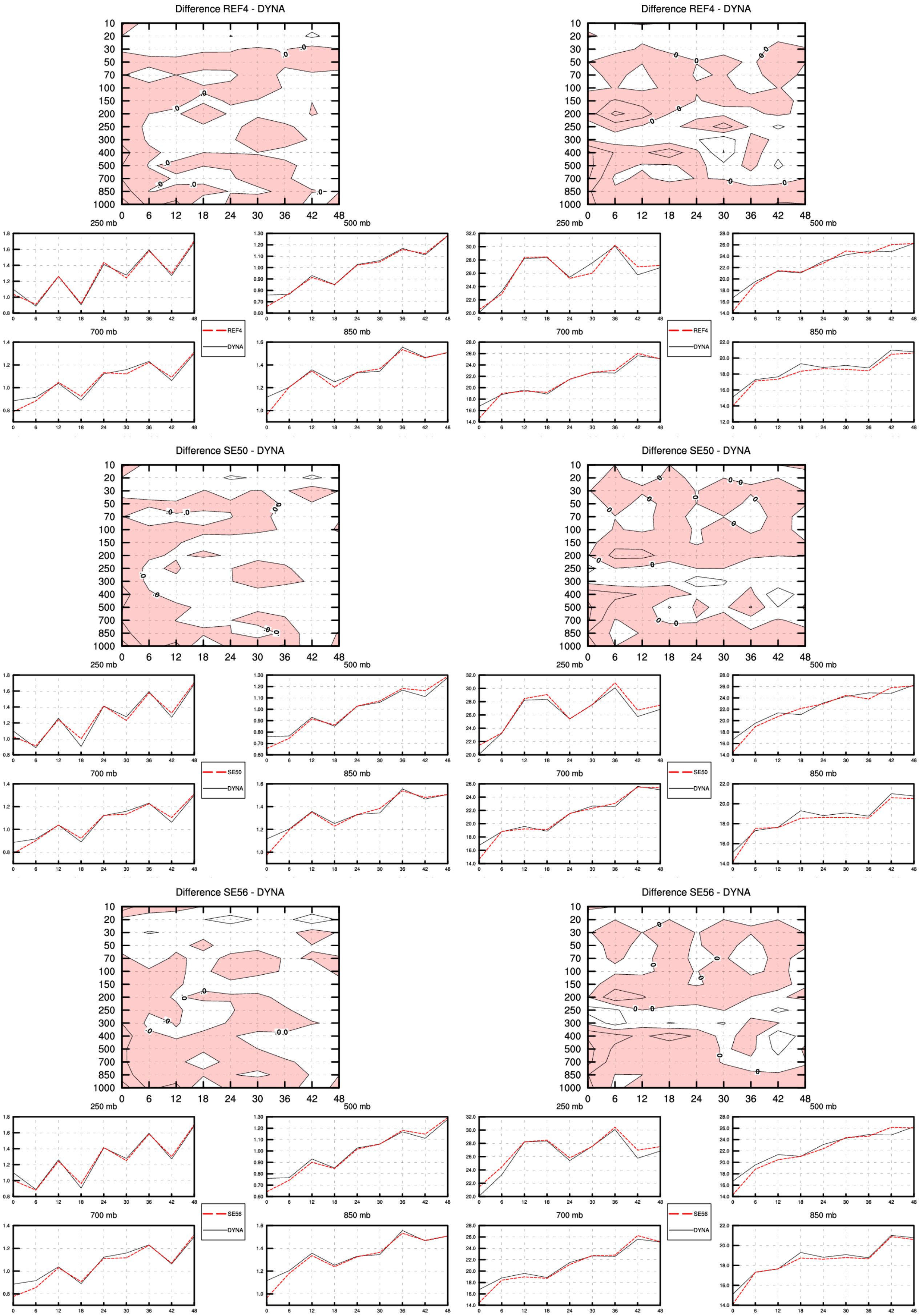

Fig. 28: RMSE against observation of T (left) and RH (right) from 20060828 till 20060923 of 00 UTC runs. Red areas denote positive impact of TEMP (top), TEMP+SEVIRI (middle) and TEMP+SEVIRI+ATOVS+AMDAR+AMV (bottom).

4 Conclusions and future work

This study was dedicated to "refinement" for more efficient use of SEVIRI data in ALADIN/HU 3DVAR system. We can summarize the results of performed impact studies as follows: the use of ensemble B matrix was found profitable compared to standard NMC method. Tuning of SEVIRI σ_o was tested, but no clear guideline was obtained. Generally, we observed small impact of SEVIRI data when comparing the analyzes and forecast against observations. We have found different impact of SEVIRI depending on the parameters and model levels. From the last experiment assessing the effect of SEVIRI data on less complex assimilation system (with regard to use of different observation types), the impact of SEVIRI was found to be similar to that of ATOVS, AMDAR and AMV assimilated in high resolution. Due to lack of time we haven't verify precipitation nor performed case studies to find the best and the worst case, perhaps also spread of error. Also it would be worth to evaluate especially an impact over local domain of interest, e.g. Carpathian basin. Up to now we have tried to get the best via tuning SEVIRI observation only. From experiment SE56 it seems that most undesirable degradation appear near surface and a combination with surface observations should be tested. Otherwise the use of SEVIRI data should be revisited, for example to use WV channels only. It is clear that SEVIRI data has an impact and with regard to its high time frequency and coverage over model domain, it is obvious source of information and more time should be dedicated to obtain maximum of its information content.

5 Acknowledgments

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Appendix

A Observation errors

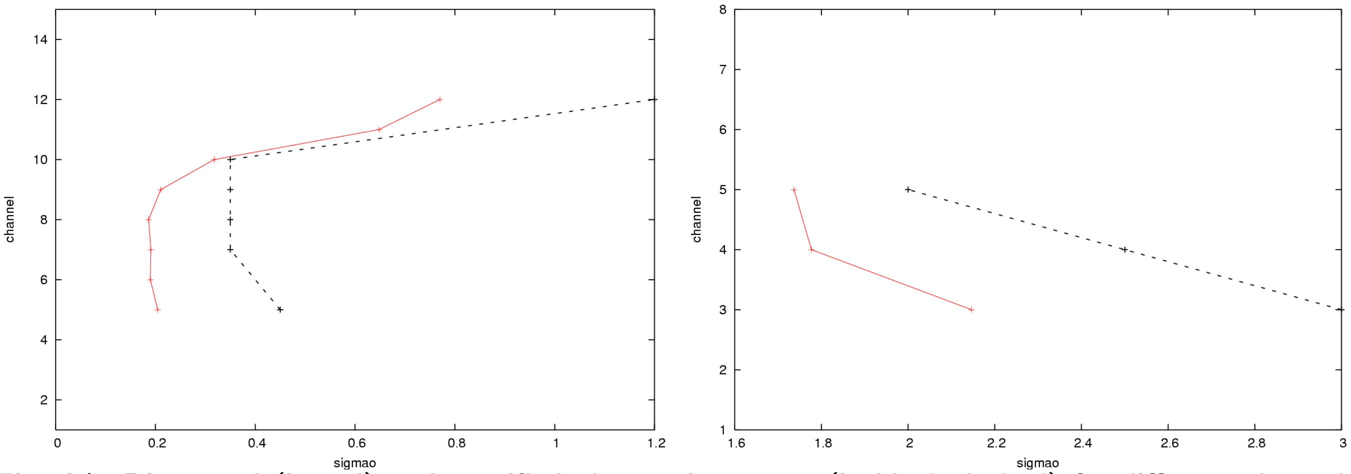

Fig. A1: Diagnosed (in red) and specified observation errors (in black dashed) for different channels of AMSU-A (left) and AMSU B (right).

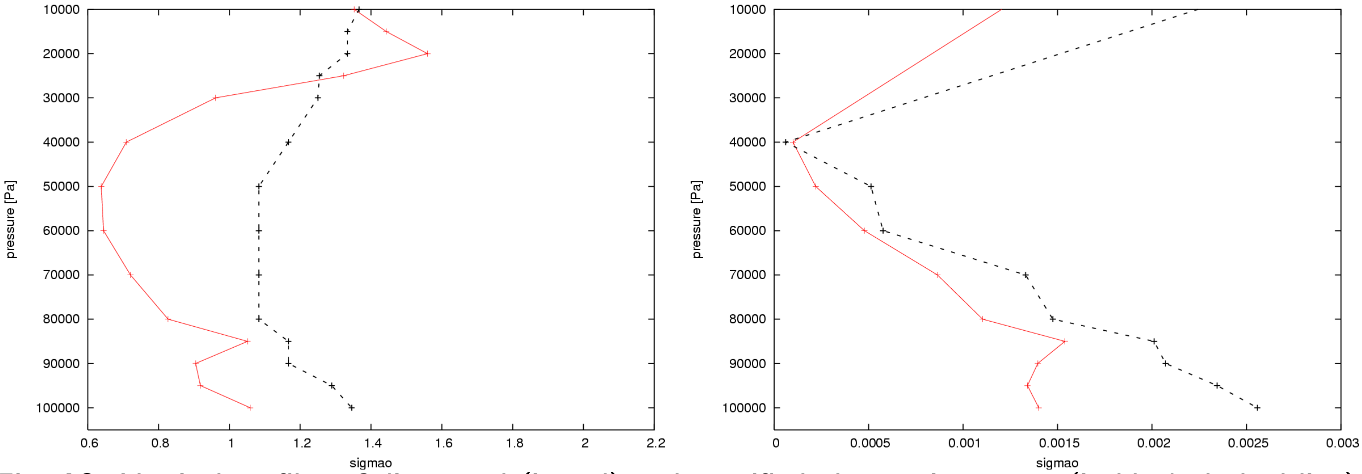

Fig. A2: Vertical profiles of diagnosed (in red) and specified observation errors (in black dashed line) for temperature (left) and specific humidity (right) of TEMP observations.

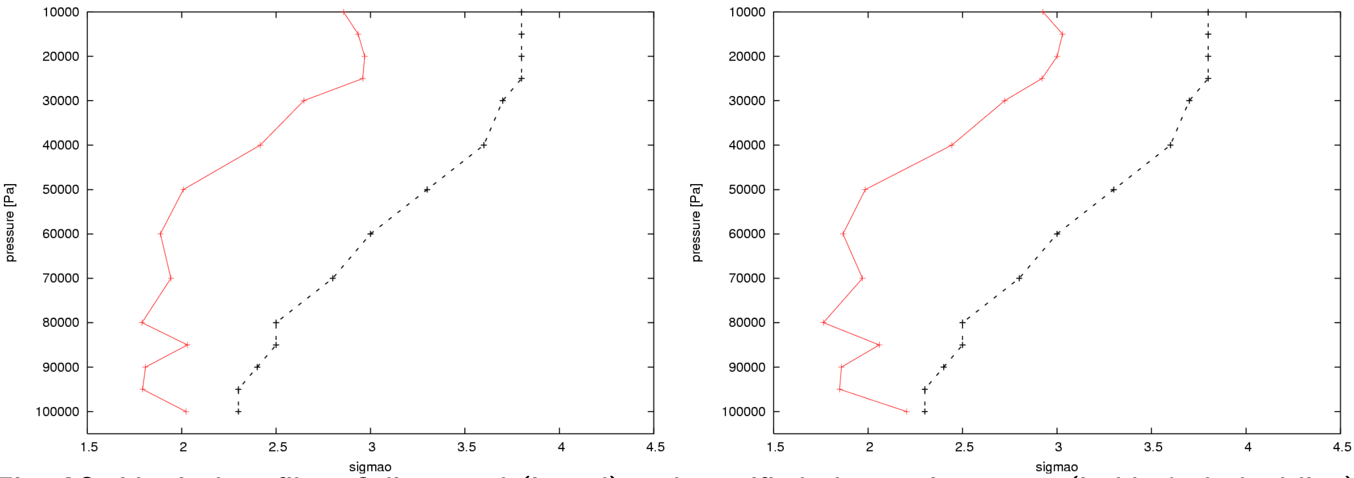

Fig. A3: Vertical profiles of diagnosed (in red) and specified observation errors (in black dashed line) for u-wind (left) and v-wind component (right) of TEMP observations.

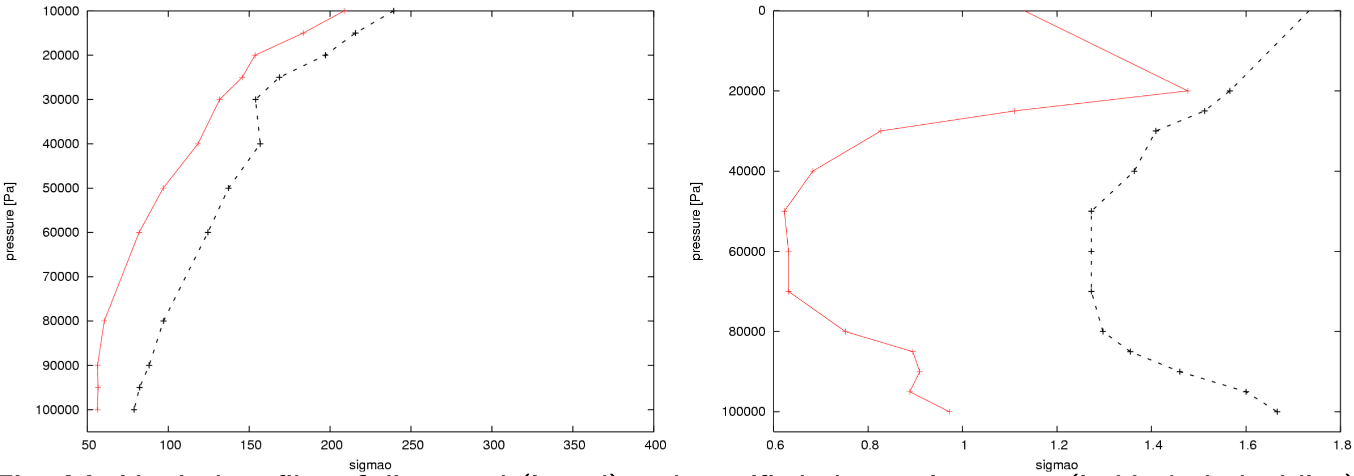

Fig. A4: Vertical profiles of diagnosed (in red) and specified observation errors (in black dashed line) for geopotential of TEMP observations and temperature of AI REP observations.

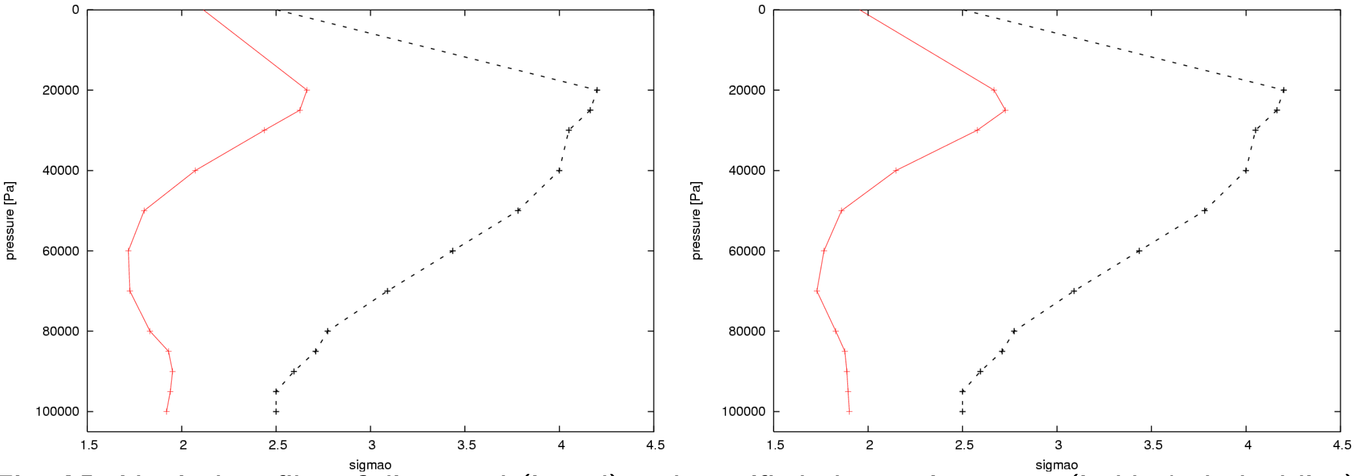

Fig. A5: Vertical profiles of diagnosed (in red) and specified observation errors (in black dashed line) for u-wind (left) and v-wind component (right) of AIREP observations.

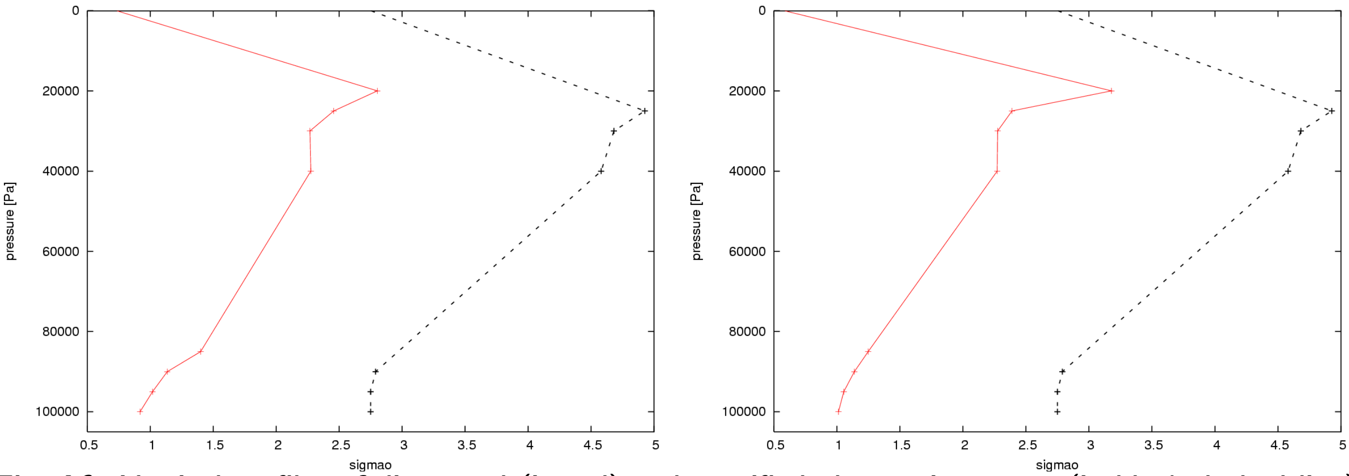

Fig. A6: Vertical profiles of diagnosed (in red) and specified observation errors (in black dashed line) for u-wind (left) and v-wind component (right) of SATOB ??? AMV observations.

B Technical notes

All scripts and namelist are stored on SGI/ALTIX 3700a under user guest2. Scripts are in scr_atro directory, where there is also small README file with notation of performed experiments and namelists in nam directory.

Veral scores (veral.*.mandout files) are stored for all performed experiments on archive in
/archive/users/guest2/SCORES/veral directory.