Testing IDFI for BlendVar II

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Contents

1 Introduction

We tested an incremental initialization method using digital filter (IDFI) for two different configuration: Blending and BlendVar. The Blending is a current operational configuration used in ALADIN/CZ, whereas, the BlendVar configuration includes 3D-Var system on the top of Blending. The aim of this study is to assess effect of IDFI in BlendVar and find a suitable setting of IDFI for BlendVar purpose.

The paper is organized as follows. A description of Blending and BlendVar configuration is presented in Sec 2. A description of IDFI method and design of DFI filter is presented in Sec 3. A investigation of coupling method, IDFI performance and effect of the filter on forecast impact is presented in Sec 4. Conclusion and discussion follow in Sec 5.

2 Model

The assimilation system uses a six-hour forward intermittent cycle as is shown in Fig 1. A six-hour forecast X_{prev} from a previous cycle is used as a first guess. This field is enhanced by surface analysis using OI and by blending with the global model Arpege using ALADIN blending technique described in [2]. The blended field X_{blend} is combined with observation in the DA system using assimilation method 3D-VAR to produce analysis X_{ana}. A six-hour forecast run from analysis is used in the next assimilation cycle as a first guess. Data assimilation scheme is performed at 00, 06, 12 and 18 UTC and the analysed fields are two components of the wind, temperature, specific humidity and surface pressure. The other model fields are cycled from the previous ALADIN guess.

The production scheme is similar as the assimilation one except of short cut-off observation and analysis initialization using Incremental Digital Filter (IDFI) method. The production scheme produces 48-h forecast from analysis at each analysis time.

Two configurations are tested in this study:

Blending includes surface analysis and ALADIN blending technique with global model.

BlendVar combining Blending and 3D-Var on the top.

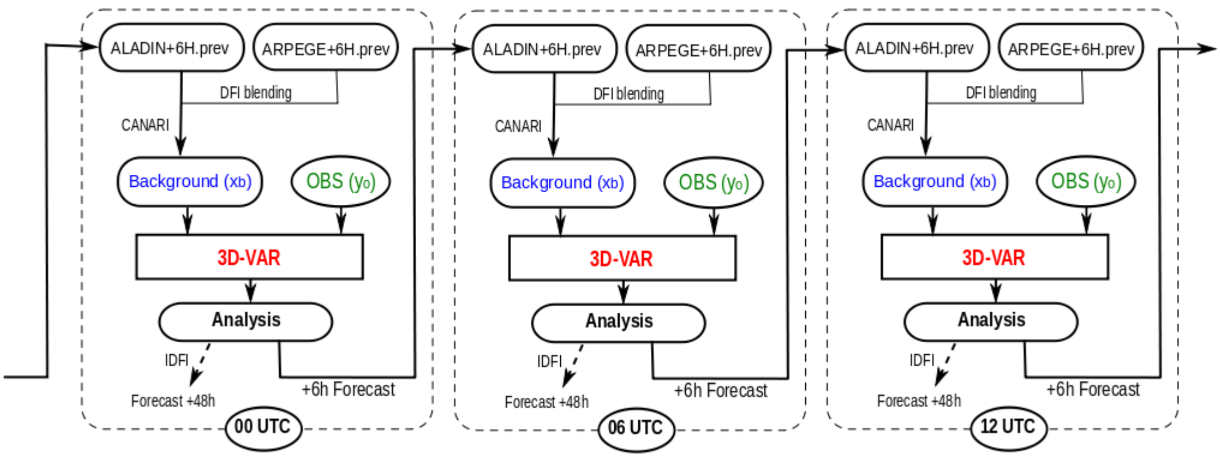


Figure 1: Data assimilation system scheme in model ALADIN/CZ.

3 The IDFI method

Initialization procedure is applied to damp spurious high frequency oscillations (a noise) when starting forecast integration from analysis. In Aladin model, initialization is realized through application of time filter with digital filter technique (DFI) to low-pass filter analysis in temporal space. According to [4] this scheme has been found to be highly efficient in damping high frequency noises.

A special form of incremental digital filter initialization (IDFI) scheme is used in our model to damp the noises. This scheme is computed in the two steps:

$$\mathbf{X}_{bias} = \mathbf{X}_{prev}^{DFI} - \mathbf{X}_{prev} \tag{1}$$

$$\mathbf{X}_{ini} = \mathbf{X}_{ana}^{DFI} - \mathbf{X}_{bias} \tag{2}$$

where $\mathbf{X}$ represents model state, *ini* here denotes initialized model state and *DFI* denotes the low-pass time filter. Design of this specific low-pass filter is described in the following section.

3.1 Design of DFI low-pass filter

In practice, Lynch (1997) recommended to first perform a backward integration with just the dry adiabatic dynamics (reversible), from $t = 0$ to $t = -T_s$. Applying DFI procedure gives a filtered field centered at $t = -T_s/2$. Then a forward integration from $t = -T_s/2$ to $t = +T_s/2$ using the full model with physics results in a field centered at $t = 0$, filtered for the second time including filtering of the effects of irreversible diabatic processes. This scheme is shown in the Fig 2.

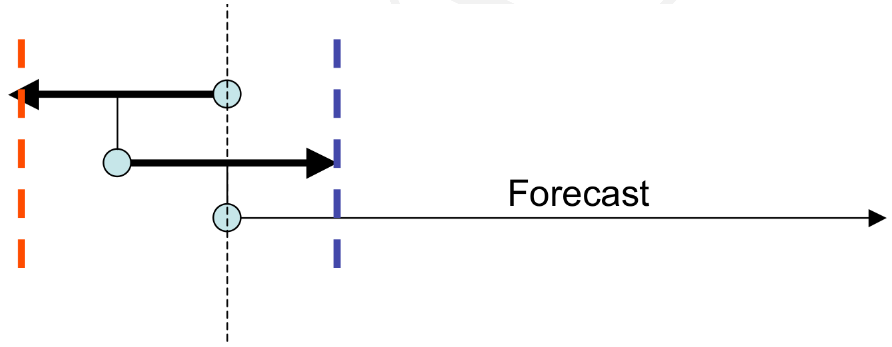


Figure 2: Non-recursive digital filter applied to both the backward (adiabatic) and forward (diabatic) steps.

The first performance parameter we choose is cutoff frequency sharpness. A low-pass filter is designed to block all frequencies above the cutoff frequency (the stopband), while passing all frequencies below (the passband). We define a period τ_s such that waves with periods shorter than this are to be filtered. Then the cut-off frequency is given by:

$$\theta_s = 2\pi\Delta t/\tau_s \tag{3}$$

where Δt is a time-step of model integration. The minimum time-span for the backward-forward scheme is given by:

$$T_{min} \approx (\frac{1}{\pi} cosh_{-1} \frac{1}{\sqrt{r}})\tau_s \tag{4}$$

where r is a ripple ratio providing wavy variations in the amplitude of the passed frequencies. A good compromise and a common choice of passband ripple is about 6% ($r = 0.06$). The time span of integration is defined as $T = 2M\Delta t$ gives a filter of order $N = 2M + 1$.

4 Results

4.1 Time/space-consistency coupling

Experiment was performed for one-day (07.07.2014, 12UTC), when two different coupling techniques have been tested in production, namely time-consistency and space-consistency. As the name already suggested, these techniques were different in the sense the 3D-Var analysis and the global model (ARP) coupling have been chosen in such way that the information provided by the files was consistent in time, or respectively in space. In practice, time-consistency coupling use Arpege +00H forecast ARPEGE/LBC0, whereas space-consistency coupling use 3D-Var analysis ANALYSIS/LBC0 within time-integration.

The coupling methods were studied for both Blending and BlendVar configuration with/without initialization method (idfi/noidfi). We examine the global noise level measurements performed by the mean-absolute surface pressure tendency $MSPT$ (more details in [4]).

The variation of $MSPT$ during the first 4h-forecast is shown in Fig 3. The configuration BlendVar without initialization (noidfi.arp) produce a noise in the first 2-3 hour of forecast that is slightly reduce by space-consistency coupling (noidfi.scc). Applying initialization filter (idfi) is able to reduce the noise in BlendVar scheme more significantly. Note that applying IDFI scheme in combination with space-consistency coupling (idfi.scc) is able to reduce the noise more effectively than with time-consistency coupling (idfi.arp). According to these results was concluded that to reduce effectively noises **in BlendVar configuration, the space-consistency coupling is needed.**

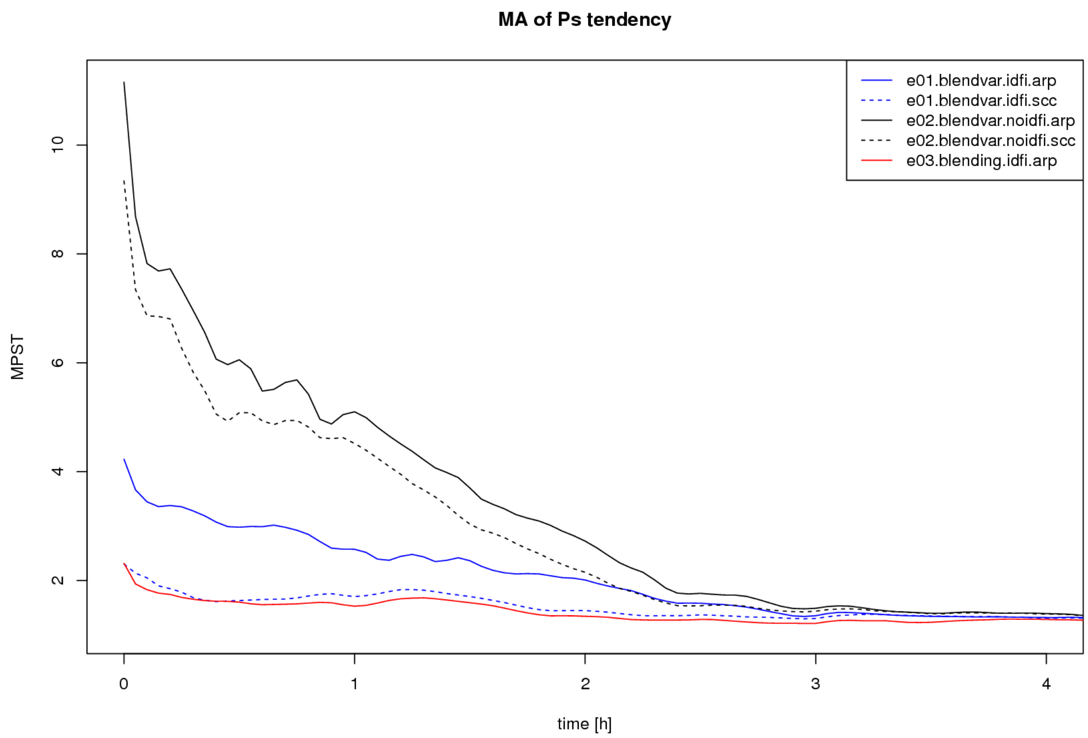


Figure 3: Time evolution (hours) of the mean absolute surface pressure tendency $MSPT$ averaged over the interior model domain.

4.2 Re-tuning of IDFI

The DFI filter that is included in IDFI scheme is set up to filter short-waves in the Blending scheme (default) with time-period shorter than 5400 s (it is related with space size ∼ 141 km). A new setting for BlendVar configuration was performed to allow the short waves in analysis (including in addition observation increments). This new scheme filters is re-tuned to filter very-short waves with time-period less than 1800 s (in space size ∼ 47 km). The re-tuning was performed through filter performance parameters according to 3 and 4. Filter settings are described in Tab 1.

Name	**Configuration**	$\tau_{\mathbf{s}}$**[s]**	$\mathbf{\Delta t}$**[s]**	$\theta_{\mathbf{s}}$**[Hz]**	$\mathbf{T_{min}}$**[min]**	**M[1]**
IDFI.def	Blending	5400	180	$\pi/15$	63	11
IDFI.new	BlendVar	1800	180	$\pi/5$	20	5

The variation of *MSPT* during the first 3h-forecast is shown for BlendVar configuration with *IDFI.def* and *IDFI.new* in Fig 4. Note that *IDFI.new* is able to reduce noises (on half value of MSPT) comparing with *noidfi* experiment.

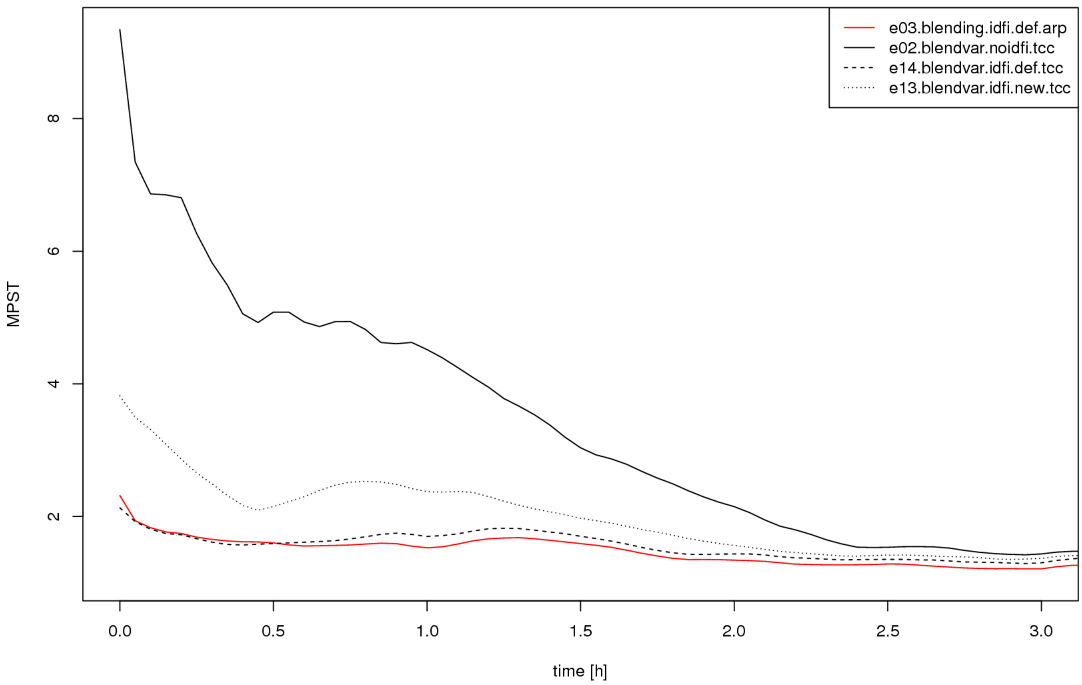


Figure 4: Time evolution (hours) of the mean absolute surface pressure tendency $MSPT$ averaged over the interior model domain.

4.3 Forecast impact

We examine forecast impact of space-consistency coupling (SCC), IDFI.def and IDFI.new initialization for BlendVar configuration. The SCC method is applied within time-integration in both assimilation and production runs. The IDFI filtering is applied only in production run. Forecast impact of changes is verified against radiosondes by VERAL plots. Relative humidity scores are examined by applying VERAL namelist modification (LNEIGE=FALSE) described by Tonda.

4.3.1 Impact of SCC

The space-consistency coupling method SCC is examined: separately within assimilation cycle (SCC-ASSIM) and within both assimilation and production runs (SCC-PROD). As a reference experiment is used the current pre-operative experiment provided by Alena (x19) based on the ARPEGE/LBC0 coupling method (both assimilation and production). These experiments are investigated for one-month period 25.6.-30.7.2015. The SCC-ASSIM is assessed for 6h-forecast run from analysis terms (6 and 18 UTC), whereas the SCC-PROD is assessed for 0-48h forecast run from 0 and 12UTC.

1. **REF: x19** – *blendvar.idfi.arp*
2. **EXP: e18** – *blendvar.idfi.scc*

The forecast impact of SCC method is summarized in Fig 5 for SCC-ASSIM (left) and SCC-PROD (right). The SCC impact was detected primarily for 6h-forecast, whereas decent or no impact was observed for the longer forecast ranges (not shown). Note that applying SCC has positive impact on RMSE and BIAS of RH (between 1000-300hPa) in both SCC-ASSIM and SCC-PROD. Impact on precipitation forecast is almost neutral.

ASSIM +6H

06 UTC	RMSE					BIAS				
Level [hPa]	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	0	0	0	0	0	0
1000	-	0	0	0	0	0	+	0	-	0
850	0	0	0	0	0	0	0	0	0	0
700	0	0	0	+	0	0	0	0	+	0
500	0	+	0	0	0	0	+	0	0	0
400	0	0	0	0	0	0	0	0	0	0
300	0	0	0	0	0	0	+	0	0	0
250	0	0	0	0	0	0	+	0	0	0
200	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

18 UTC	RMSE					BIAS				
Level [hPa]	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0	0	0	0
850	0	0	0	0	0	0	0	0	0	0
700	0	+	0	-	0	0	0	0	0	0
500	0	+	0	0	0	0	-	0	0	+
400	0	+	0	0	0	0	+	0	-	0
300	0	-	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

PROD +6H

00 UTC	RMSE					BIAS				
Level [hPa]	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	0	0	0	0	0	0
1000	0	-	0	0	0	0	0	0	0	0
850	0	0	0	0	-	0	0	0	0	0
700	0	+	0	0	0	0	+	0	0	0
500	0	0	0	+	0	0	0	0	0	0
400	0	+	0	0	0	0	0	0	0	0
300	0	0	0	0	+	0	0	0	0	+
250	+	+	0	0	0	+	+	0	0	0
200	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

12 UTC	RMSE					BIAS				
Level [hPa]	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	0	0	0	0	0	0
1000	0	+	0	+	0	0	+	0	+	0
850	0	0	0	-	0	0	+	0	-	0
700	0	+	0	0	0	0	+	0	0	0
500	0	-	0	0	0	0	0	0	0	0
400	0	+	0	0	0	0	+	0	0	0
300	0	+	0	0	0	0	+	0	0	0
250	0	0	0	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

Figure 5: Impact of SCC on 6h-forecast for SCC-ASSIM (left) and SCC-PROD (right). Positive/negative impact represented by green/red color.

In summary, the SCC method provides better results primarily in short-range humidity forecast and **could be recommended for the further experiments in both assimilation and production runs**.

4.3.2 Impact of IDFI

We investigated a forecast impact of IDFI.new, IDFI.def and NOIDFI (without IDFI filter) in production run. These experiments are based on SCC method discussed above. The forecast impact from 0 and 12UTC runs are assessed during the period 25.6.-10.7.2014.

1. **NOIDFI**: e17 – *blendvar.noidfi.scc*
2. **IDFI.def**: e18 – *blendvar.idfi.def.scc*
3. **IDFI.new**: e16 – *blendvar.idfi.new.scc*

The veral scores are summarized for 6h-forecast in Fig 6 (left) and 12h-forecast in Fig 6 (right). We detected slight differences between the experiments. Using IDFI.def (green) has positive impact on T in low-troposphere (850-700 hPa) and RH in middle-troposphere (500-400 hPa) propagated also in 12h-forecast. On the other hand not applying IDFI filter (blue) has positive impact on wind speed (WS) and wind direction (WD) near surface. Note that the weaker IDFI.new (orange) filter is able to combine both positive impacts on mid-tropospheric RH (500-300 hPa) and near-surface WD propagated also in 12h-forecast.

PROD +6H

00 UTC

Level [hPa]	RMSE					BIAS				
	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0	0	0	0
850	0	0	0	0	mdfi	dfi	0	0	0	0
700	dfi	0	0	0	0	0	0	0	0	0
500	0	dfi	0	0	0	0	dfi	0	0	0
400	0	dfi	0	0	0	0	0	0	0	0
300	0	mdfi	0	0	0	0	0	0	0	nodfi
250	0	dfi	0	0	0	0	0	0	0	0
200	0	0	0	dfi	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

12 UTC

Level [hPa]	RMSE					BIAS				
	T	RH	G	WD	WS	T	RH	G	WD	WS
0	dfi	0	0	0	0	0	0	0	m/no	0
1000	0	0	0	0	m/no	0	0	0	0	m/no
850	dfi	0	0	0	0	0	0	0	0	0
700	0	0	0	0	0	0	0	0	0	0
500	mdfi	mdfi	0	dfi	mdfi	0	0	0	0	0
400	0	0	0	0	0	0	mdfi	0	0	0
300	0	0	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	mdfi	0	0	0
200	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

PROD +12H

00 UTC

Level [hPa]	RMSE					BIAS				
	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	0	0	0	0	mdfi	0
1000	0	0	0	0	0	0	0	0	mdfi	0
850	0	0	0	m/no	0	0	0	0	nodfi	0
700	0	0	0	0	0	0	0	0	0	0
500	0	dfi	0	0	0	0	dfi	0	0	0
400	0	nodfi	0	0	0	0	nodfi	0	0	0
300	0	0	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	nodfi	0	0	0
200	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

12 UTC

Level [hPa]	RMSE					BIAS				
	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	0	0	0	0	mdfi	0
1000	0	mdfi	0	nodfi	dfi	dfi	0	0	nodfi	0
850	0	mdfi	0	0	dfi	0	0	0	0	0
700	0	0	0	0	0	0	0	0	mdfi	0
500	0	mdfi	0	0	dfi	0	0	0	mdfi	0
400	0	mdfi	0	0	0	0	0	0	mdfi	0
300	mdfi	0	0	0	0	0	0	0	0	0
250	mdfi	0	0	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

Figure 6: Forecast impact of IDFI methods on 6h and 12h-forecasts run from 00 and 12 UTC. Experiments NOIDFI/IDFI.def/IDFI.new are represented by blue/green/orange colors.

In addition, we examined a precipitation forecast for the IDFI experiments. Because of convective weather conditions during the tested period, precipitation scores were dependent on forecast ranges. To reduce the double penalty effect in mesoscale, we assess the 24h-cumulative precipitation forecast from 12UTC (more convection occures) and the 6h-cumulative precipitation forecast from 00UTC. The scores FBI, POD and FAR for all precipitation tresholds are shown in Fig 7 (00UTC) and Fig 8 (12UTC). According to the results applying IDFI (e18, e16) has positive effect on FAR and POD scores. Note that the weaker IDFI.new has similar results as IDFI.def. In addition the IDFI.new has slightly better results in POD for 24h-cumulative precipitation forecast.

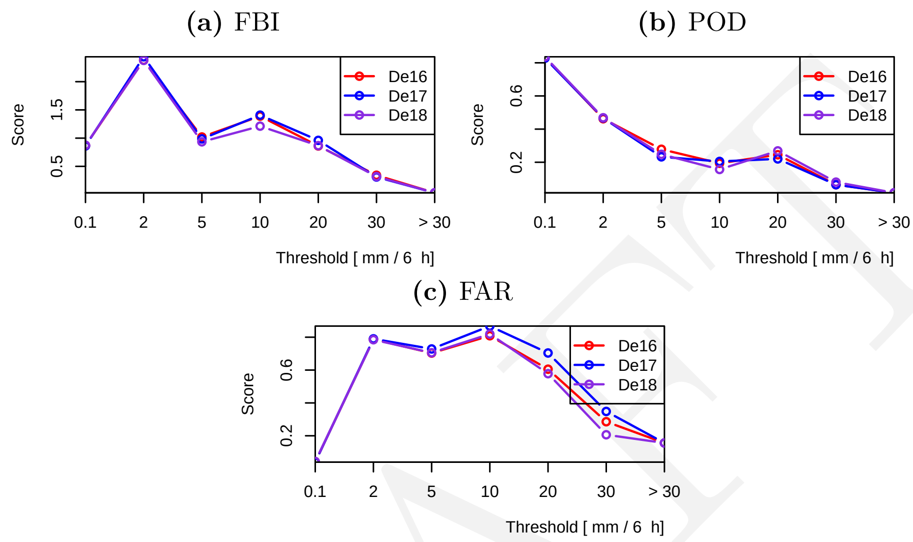


Figure 7: Impact of 6h-cumulative precipitation forecasts (F06) run from 00UTC.

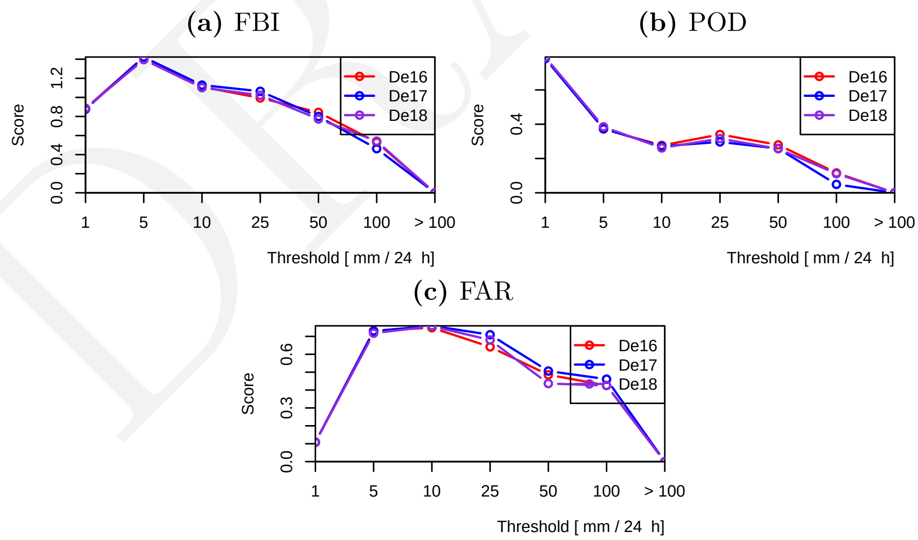


Figure 8: Impact of 24h-cumulative precipitation forecasts (F24) run from 12UTC.

In summary, applying IDFI initialization method provides better results in precipitation forecast as well VERAL scores. According to the results above the modified (weaker) filter **IDFI.new is recommended to initialize the BlendVar analysis in production.**

4.4 PRE-OPER EXPERIMENT

We assess the experiment IDFI.new with applied SCC method in both assimilation and production cycle against the reference experiment (x19) provided by Alena. Both experiments are examined during the period 25.6.-30.7.2014. Forecasts from 0 and 12UTC are assessed by Veral and Veral.prec.

1. **REF: X19**; *blendvar.idfi.def.arp*
2. **TEST: E16**: *blendvar.idfi.new.scc*

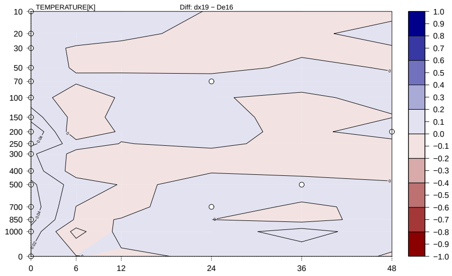
The veral scores are summarized in Fig 9. Positive/negative impact of TEST experiment is represented by green/red color. The TEST experiment provides better results in humidity (RH) forecast between 1000-300 hPa (from 12UTC run), wind speed (WS) between 500-250hPa as well as wind direction (WD) near the surface (1000hPa). Veral scores (from 0 and 12UTC) of RMSE and BIAS for temperature (T), humidity (RH), wind speed (WS) and wind direction (WD) are provided additionally in Fig 10, Fig 11 and Fig 12, Fig 12.

00 UTC	RMSE					BIAS				
Level [hPa]	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	0	0	0	0	0	+
1000	0	0	0	0	0	0	0	0	+	0
850	0	0	0	+	0	0	0	0	0	0
700	0	0	0	-	0	0	0	0	0	-
500	0	0	0	+	+	0	0	0	+	+
400	0	0	0	0	0	0	0	0	0	0
300	0	-	0	0	+	0	-	0	-	0
250	0	0	0	-	+	0	0	0	0	0
200	0	0	0	+	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

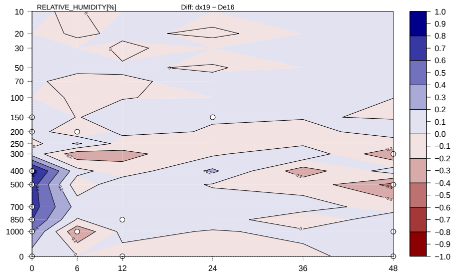
12 UTC	RMSE					BIAS				
Level [hPa]	T	RH	G	WD	WS	T	RH	G	WD	WS
0	0	0	0	0	+	0	0	0	0	0
1000	0	+	0	+	0	0	0	-	0	0
850	0	0	0	0	0	0	0	-	0	0
700	0	+	0	+	0	0	0	0	+	0
500	0	+	0	-	+	0	0	0	0	0
400	0	+	0	0	+	0	0	0	0	0
300	0	+	0	0	-	0	+	0	0	-
250	0	0	0	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0

Figure 9: Summary of forecast impact between TEST and REF experiments run from 0 and 12UTC. Positive/negative impact of TEST is represented by green/red color.

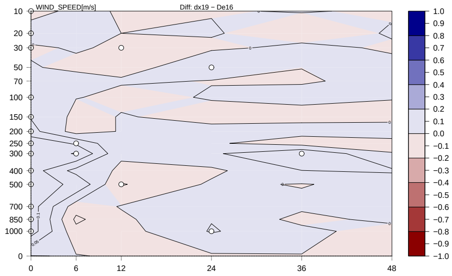
(a) RMSE temperature 00UTC



(b) RMSE RH 00UTC LNEIGE



(c) RMSE wind speed 00UTC



(d) RMSE wind direction 00UTC

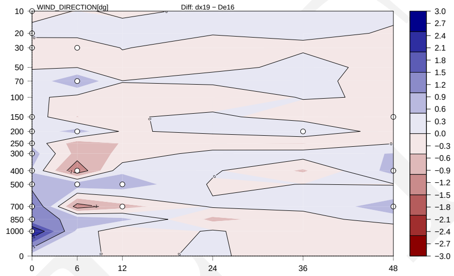
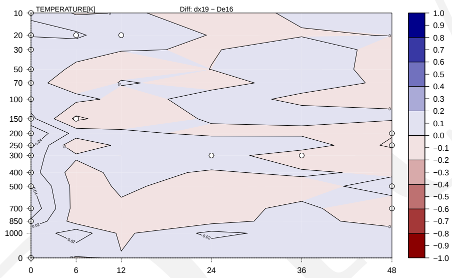
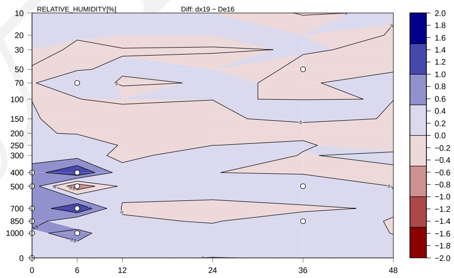


Figure 10: RMSE differences over the period 25 June - 15 July 2014 of 00UTC forecasts. Red areas denote positive impact of the BlendVAR **E16** with respect to reference **X19**. The white circles points that RMSE difference is better/worse with significance 95% two-side confidence interval.

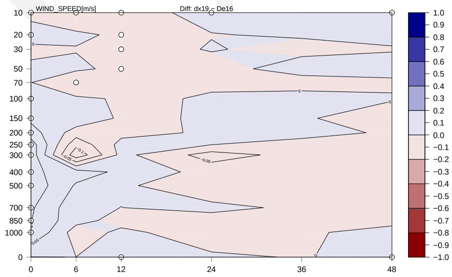
(a) RMSE temperature 12UTC



(b) RMSE RH 12UTC LNEIGE



(c) RMSE wind speed 12UTC



(d) RMSE wind direction 12UTC

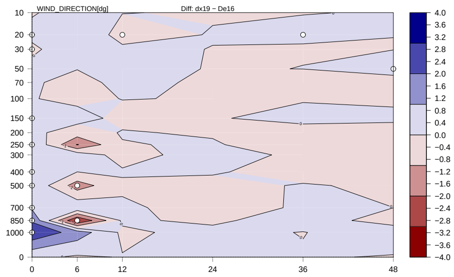


Figure 11: RMSE differences over the period 25 June - 15 July 2014 of 12UTC forecasts. Red areas denote positive impact of the BlendVAR **E16** with respect to reference **X19**. The white circles points that RMSE difference is better/worse with significance 95% two-side confidence interval.

(a) BIAS temperature 00UTC

(b) BIAS RH 00UTC LNEIGE

(c) RMSE wind speed 00UTC

(d) BIAS wind direction 00UTC

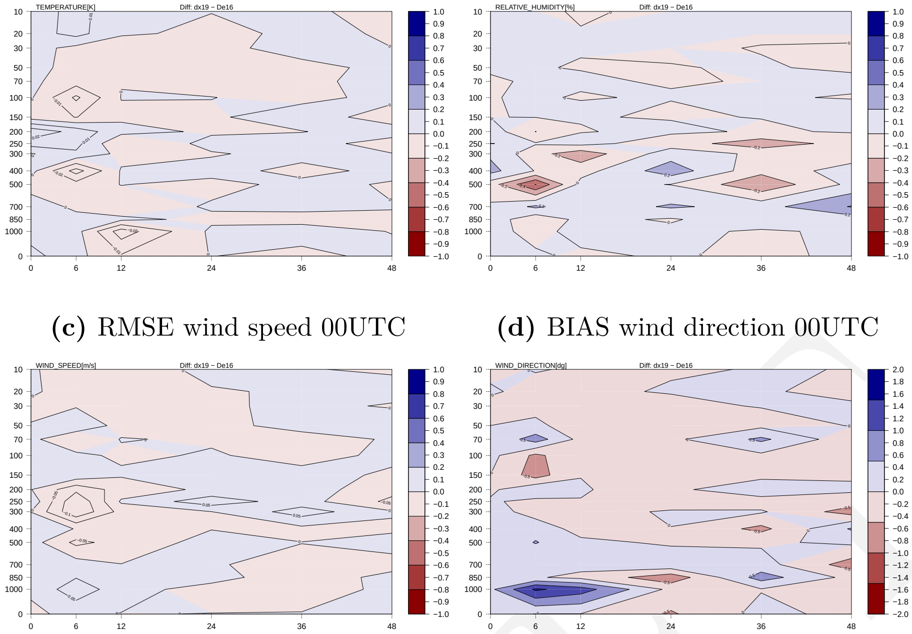


Figure 12: BIAS differences over the period 25 June - 15 July 2014 of 00UTC forecasts. Red areas denote positive impact of the BlendVAR **E16** with respect to reference **X19**.

(a) BIAS temperature 12UTC

(b) BIAS RH 12UTC LNEIGE

(c) BIAS wind speed 12UTC

(d) BIAS wind direction 12UTC

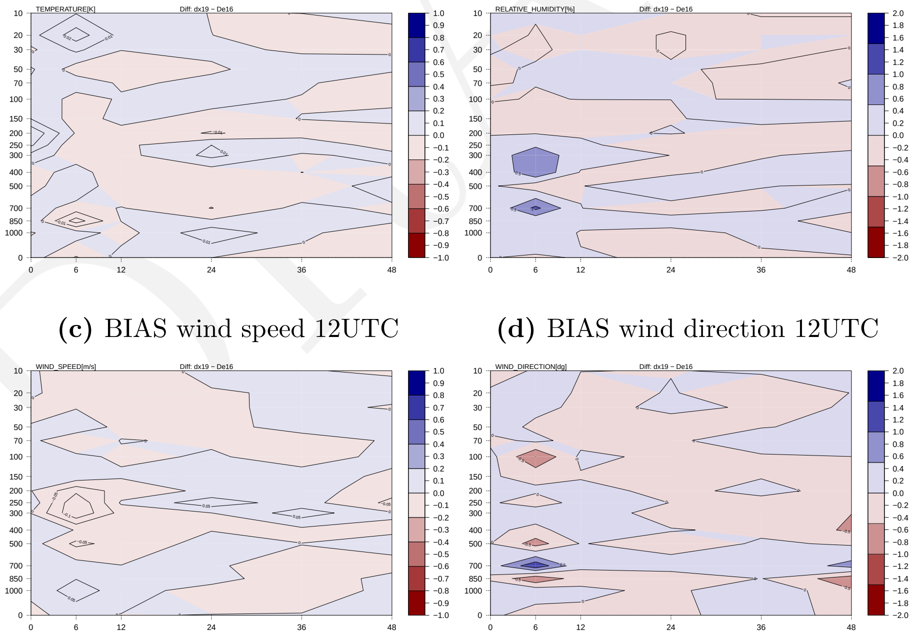


Figure 13: BIAS differences over the period 25 June - 15 July 2014 of 12UTC forecasts. Red areas denote positive impact of the BlendVAR **E16** with respect to reference **X19**.

We examined a precipitation forecast for the IDFI experiments. We compare 6h- resp 24h-cumulative precipitation forecast from 00UTC resp 12UTC as was discussed above. The scores FBI, POD and FAR for all precipitation tresholds are shown in Fig 14 (00UTC) and Fig 15 (12UTC). Note that for TEST experiment increases precipitation amount detected in FBI scores, however, the POD and FAR scores are almost neutral. Slight improvement is observed for precipitation between 2-5mm from 00UTC as well as between 25-50mm from 12UTC. In addition we compare (eye-to-eye) spatial distribution of precipitation comparing the model precipitation with radar-gauge estimation over the CZ domain. We detected also very slight differences in precipitation features (not shown).

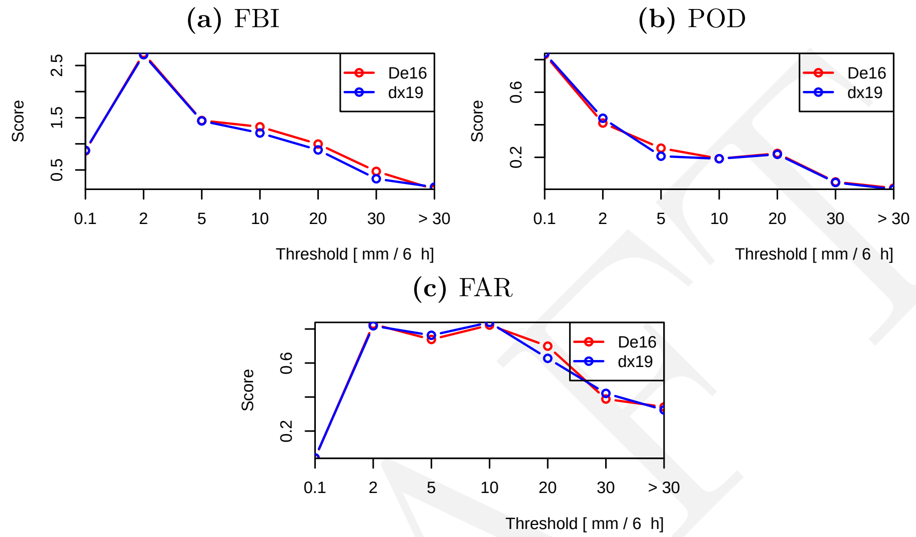


Figure 14: Impact of 6h-cumulative precipitation forecasts (F06) run from 00UTC.

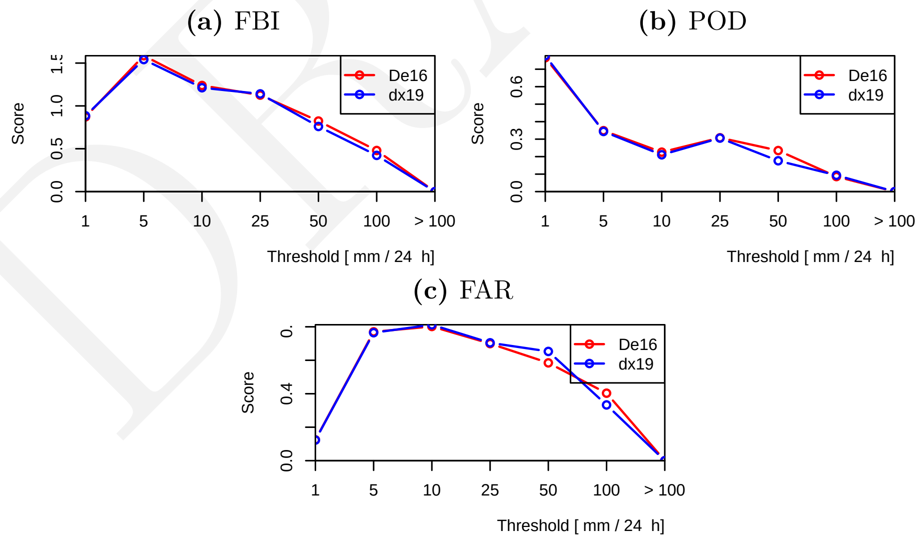


Figure 15: Impact of 24h-cumulative precipitation forecasts (F24) run from 12UTC.

In summary, the TEST experiment provides better results in short-range forecast of middle-tropospheric RH, high-tropospheric WS and WD near the surface. In addition, this weaker filter is able to preserve the ability of precipitation spin-up initialization. According to the results above **we recommended to use TEST experiment as a new reference.**

5 Conclusion

In summary, we examined that combination of IDFI scheme with space-consistency coupling (SCC) filters noises in the beginning of integration more effectively than time-consistency coupling. The positive effect of SCC was detected by the mean-absolute surface pressure tendency $MSPT$ as is shown in Fig 3. The SCC method was applied in both assimilation and production runs with positive effect on short-range forecast of humidity as is shown in Fig 5.

We performed a new setting of IDFI scheme for BlendVar configuration described in Tab 1. This setting preserves short waves that could be included in observation signal and filter very-short waves with time-period shorter than 1800 s. The new setting IDFI.new was chosen as a compromise between default setting IDFI.def and NOIDFI. According to veral scores, this new setting is able to preserve the better results in WD near the surface detected by NOIDFI as well as the better results in middle-tropospheric RH detected by IDFI.def. Positive effect of both IDFI.new and IDFI.def methods on precipitation forecast is shown in Fig 7 and Fig 8. It confirms the essential of initialization method to reduce the precipitation spin-up.

Finally, we compare TEST experiment (IDFI.new + SCC) against the reference REF (IDFI.def). The weaker IDFI filtering in TEST experiment is able to improve short-range forecast of RH (in MT), WS (in HT) and WD (near surface) that is probably by preserving observation increments. In addition the TEST setting provides sufficient spin-up initialization of precipitation (as REF) as is shown in Fig 14 and Fig 15.

To conclude the IDFI.new setting with SCC provides encouraging scheme for BlendVar configuration that is able to reduce noises in analysis and preserves a small-scale observation signal.

Technical Notes

Experiments (on yaga):

```
TEST: /home/mma/mma209/work/exp/e16
REF:  /home/mma/mma153/work/exp/x19
```

Path to veral scores (on yaga):

```
/work/mma209/verification/CY38t1_R2/aRESULTS_IDFI_rep/
```

References

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