Regional Cooperation for
Limited Area Modeling in Central Europe

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Studies with grid-point sigmaB maps and different assimilation setups

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DHMZ SHMU OMSZ ZAMG ROMANIA ANM

Outline

- Sigma_b maps
  - What the sigma_b maps do and how to switch them on
  - Variation of sigma_b maps produced by AEARP
  - Performance - single obs, full obs
  - Potential problems
  - Arome bug
  - Local generation of sigma_b maps
- SIGMAO_COEF
  - Bug in cycle 38t1_bf03
  - Division by SIGMAO_COEF in defrun.F90 wanted behavior or bug?
- Case study over flood event 2013

What the sigma_B maps do

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- 3DVAR equations for control variable, grid point sigma_bs are denoted by $\mathbb{S}$. By default covariances are homogeneous and isotropic, but by $\mathbb{S}$ we can introduce nonhomogenity.

$$\mathbf{B}^{\frac{1}{2}} = \mathbf{K} \underbrace{\left(\mathbf{F}\mathbb{S}\mathbf{F}^{-1}\mathbf{D}\mathbf{V}\mathbf{W}\right)}_{\mathbf{U}} \tag{1}$$

$$\delta x = \mathbf{B}^{\frac{1}{2}}\chi \tag{2}$$

$$J(\chi) = \frac{1}{2}\chi^T\chi + \frac{1}{2}\left[\mathbf{y} - H(\mathbf{x_b}) - \mathbf{H}\mathbf{B}^{\frac{1}{2}}\chi\right]^T \mathbf{R}^{-1}\left[\mathbf{y} - H(\mathbf{x_b}) - \mathbf{H}\mathbf{B}^{\frac{1}{2}}\chi\right] \tag{3}$$

$$\nabla J(\chi) = \chi + \mathbf{B}^{\frac{T}{2}}\mathbf{H}^T\mathbf{R}^{-1}\left[\mathbf{y} - H(\mathbf{x_b}) - \mathbf{H}\mathbf{B}^{\frac{1}{2}}\chi\right] \tag{4}$$

$$\nabla J(\chi) = \chi + \mathbf{U}^T\mathbf{K}^T \underbrace{\mathbf{H}^T\mathbf{R}^{-1}\left[\mathbf{y} - H(\mathbf{x_b}) - \mathbf{H}\mathbf{B}^{\frac{1}{2}}\chi\right]}_{\mathbf{v}} \tag{5}$$

$$\mathbf{K} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ \mathbf{L} & 1 & 0 & 0 \\ \mathbf{M} & \mathbf{N} & 1 & 0 \\ \mathbf{O} & \mathbf{P} & \mathbf{Q} & 1 \end{pmatrix} \quad \mathbf{K}^T = \begin{pmatrix} 1 & \mathbf{L}^T & \mathbf{M}^T & \mathbf{O}^T \\ 0 & 1 & \mathbf{N}^T & \mathbf{P}^T \\ 0 & 0 & 1 & \mathbf{Q}^T \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad \mathbf{v} = \begin{pmatrix} \zeta \\ \eta \\ T \\ q \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ T \\ 0 \end{pmatrix} \tag{6}$$

What the sigma_B maps do 2

- We need errgrib file, AEARP ones are stored on Cougar:
  - /home/m/mxpt/mxpt001/arpege/oper/assim/$YYYY/$MM/DD/rNT/errgribvor ,
  - /home/m/mxpt/mxpt001/arpege/oper/assim/$YYYY/$MM/DD/rNT/errgrib_scr ,
- Set in NAMJG: LSPFCE=.F. and LRDQERR=.T. (to avoid using empirical formula for ${\sigma_b}^q$) and L3DBGERR=.T. (non-separable covariance)
- Then suinfce.F90 set sigma_b:

$$\widetilde{\sigma_b}(i, var, lev) = \underbrace{\frac{\sigma_b(i, var, lev)}{\langle \sigma_b(var, lev) \rangle}}_{\text{scaling factor}} \sigma_{SP}(var, lev), \qquad \text{where} \tag{7}$$

$$\sigma_{SP}(var, lev) = REDNMC \sqrt{\sum_{kstar} \sigma^2_{SP}(kstar, var, lev)}, \tag{8}$$

Variation of sigma_b maps produced by AEARP

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Figure 1: Scaling factor for vorticity stde (vo), for unbalanced divergence (ucdv), for unbalanced temperature (uctp) and specific humidity (q), level 45 ($\sim$ 550 hPa). Scaling factors are valid for different dates. One can see quite course resolution of scaling factor produce by AEARP.

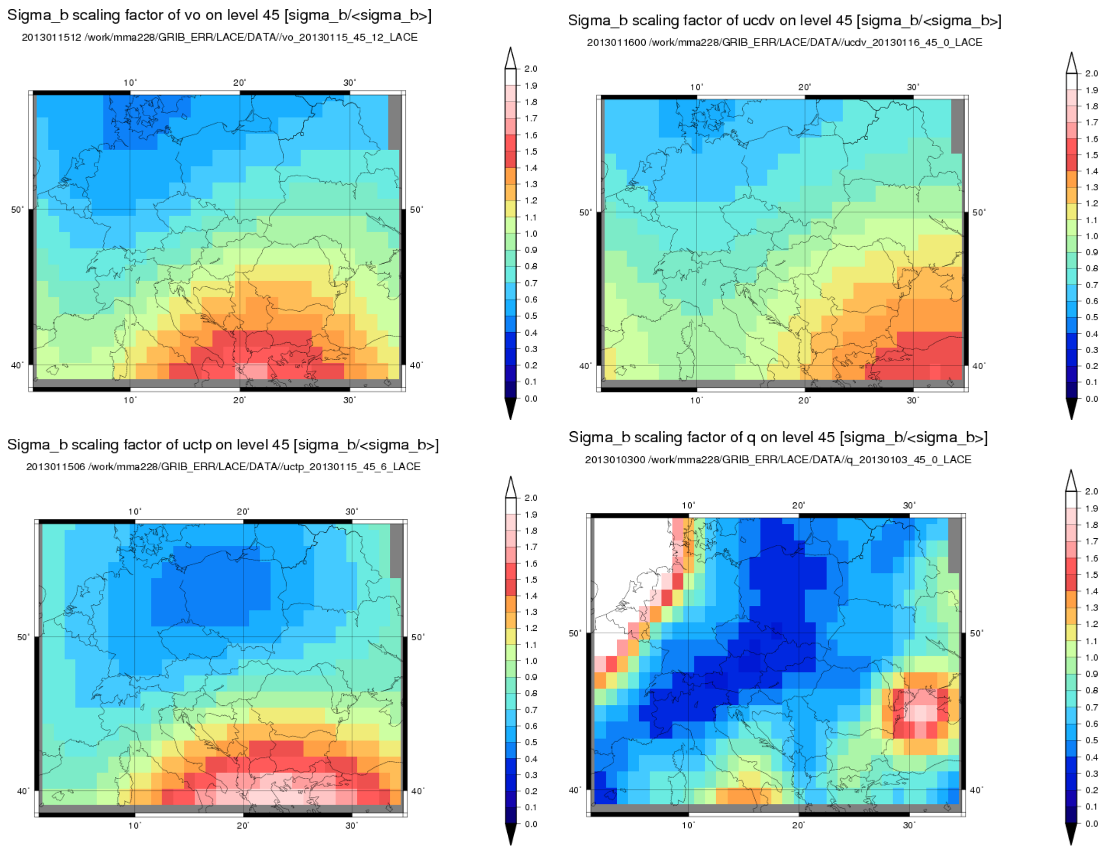
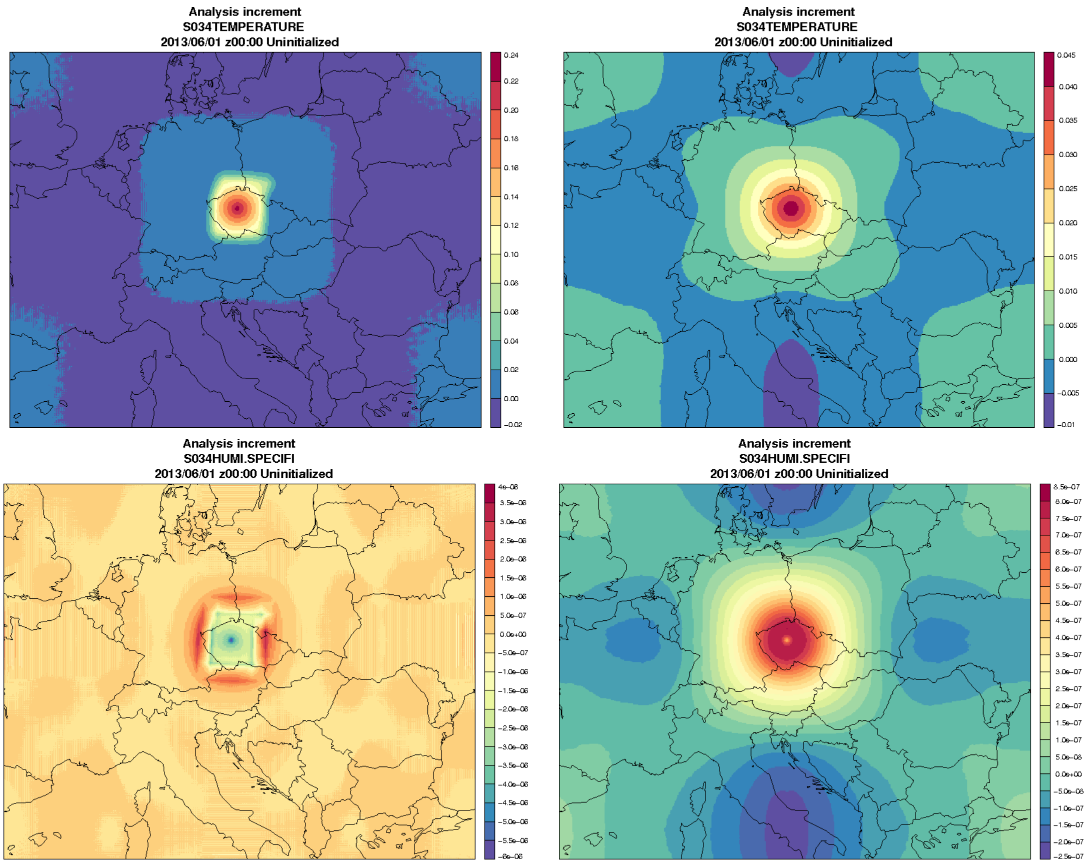


Figure 2: Scaling factor in grid-point representing Prague. Scaling factor for vorticity stde (vo), for unbalanced divergence (ucdv), for unbalanced temperature (uctp) and specific humidity (q) are plotted on level 45 ($\sim$ 550 hPa).

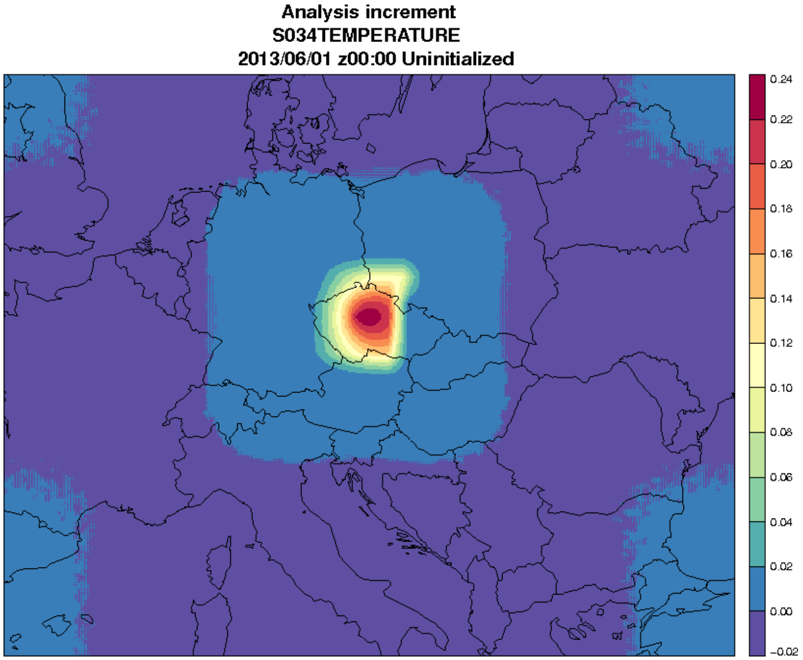
Performance Single obs

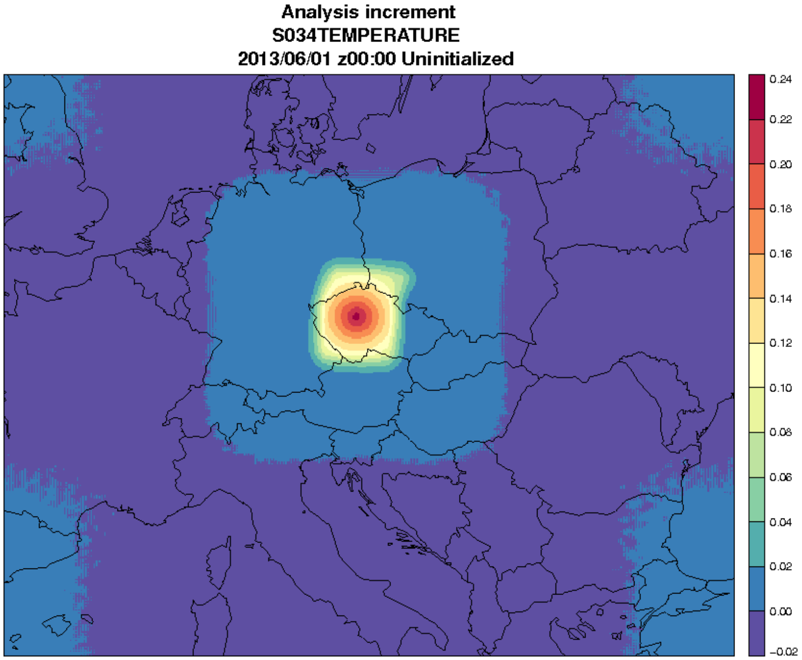
Figure 3: Grid point sigma_bs are constant over small area in left column for temperature and specific humidity. Preset value is 1 so it implies scaling factor ~ 7.58 inside small area. Reference experiment is in the right column (no sigma_b). Level 34 is approximately equivalent to 500 hPa. REDNMC = 1 in both experiments. The figures have different scales!



Performance Single obs 2

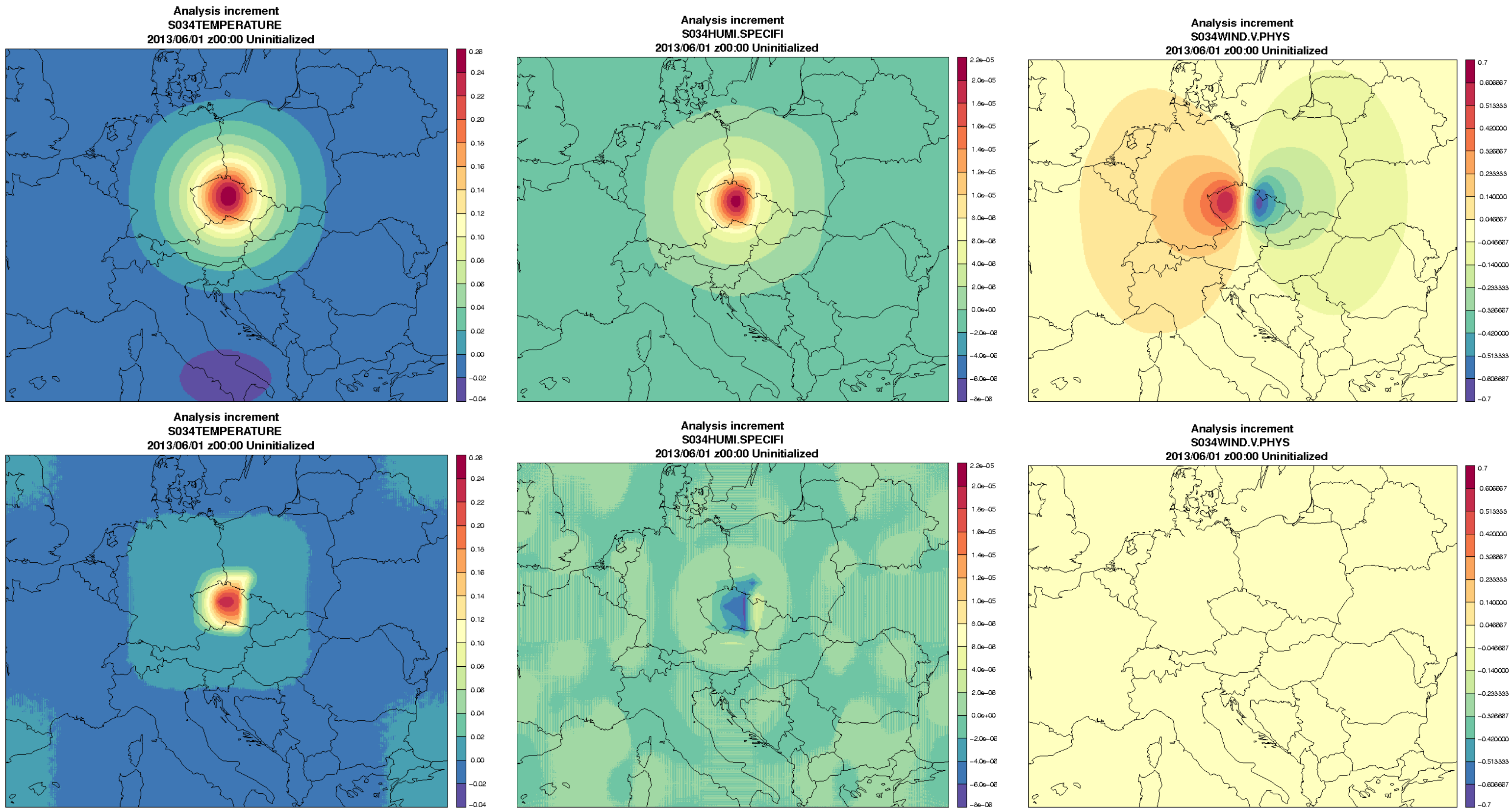
Figure 4: The left figure shows analysis increment when linearly increasing sigma_bs are used inside the small area. The right figure shows use of constant sigma_bs inside the area.





Performance Single obs 3

Figure 5: Comparison of the analyses increment for single observation of temperature. Linearly increasing values of σ_b are used inside the small area. They were applied to the vorticity (the first row) and to the temperature (the second row). Wind increments are not zero but only smaller than the scale in the second row. One should keep in mind that applying sigma_b map to the vorticity has the largest effect.



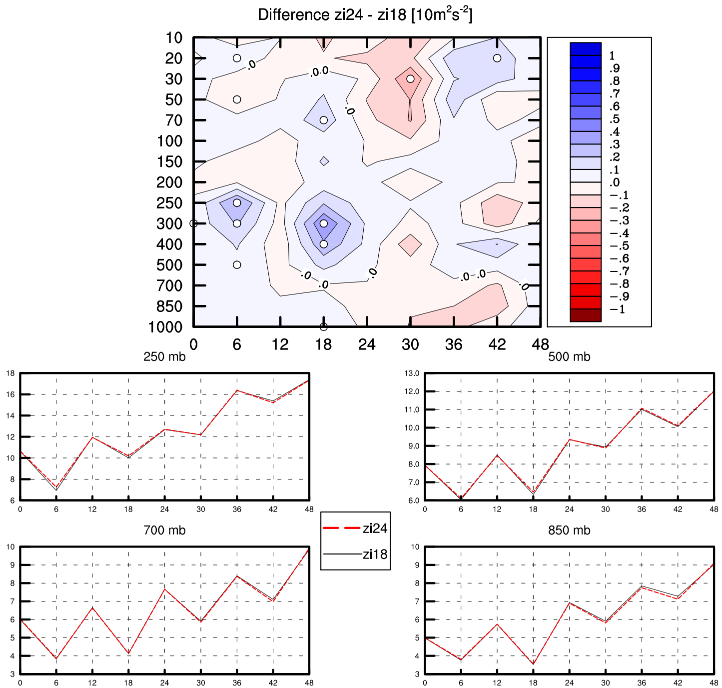
Performance Full obs

- Model setup: ALARO-0 with 3MT, cy36t1, LACE/CE domain, 4.7km 87L, ensemble B, 180s time step, 3h coupling interval
- 6h assimilation cycle, SYNOP, TEMP, AMV and AMDAR observation are used, REDNMC=1.7, SIGMAO_COEF=0.67
- Experimental period 21.5.–10.6.2013 over sever floods event in Czech republic.
- Only difference against reference experiment is use of sigma_b maps generated by AEARP
- Unfortunately scores are neutral.

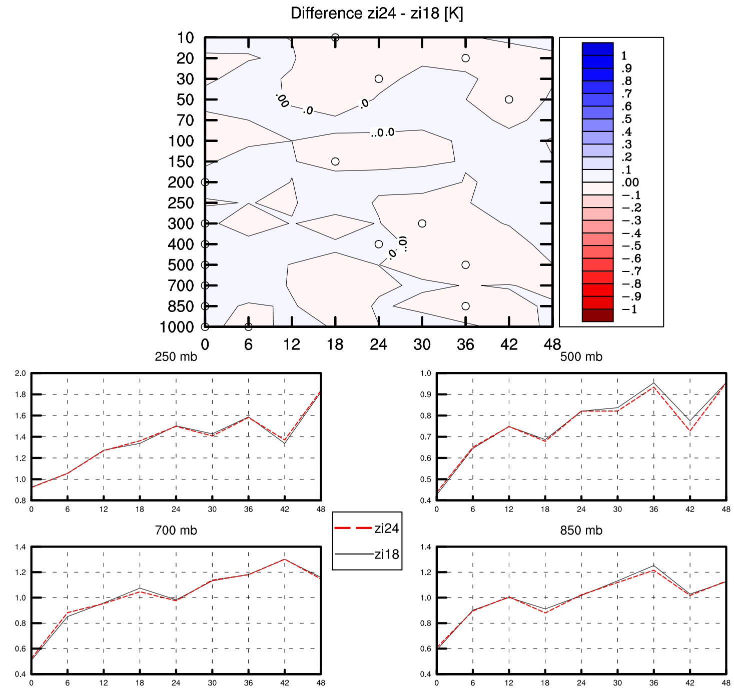
Performance Full obs 1

Figure 6: RMSE of experiment with assimilation cycle (zi24) compared to reference experiment (zi18). Verification was done against TEMP observations. Small circles show statistically significant difference.

(a) Geopotential



(b) Temperature



Performance Full obs 2

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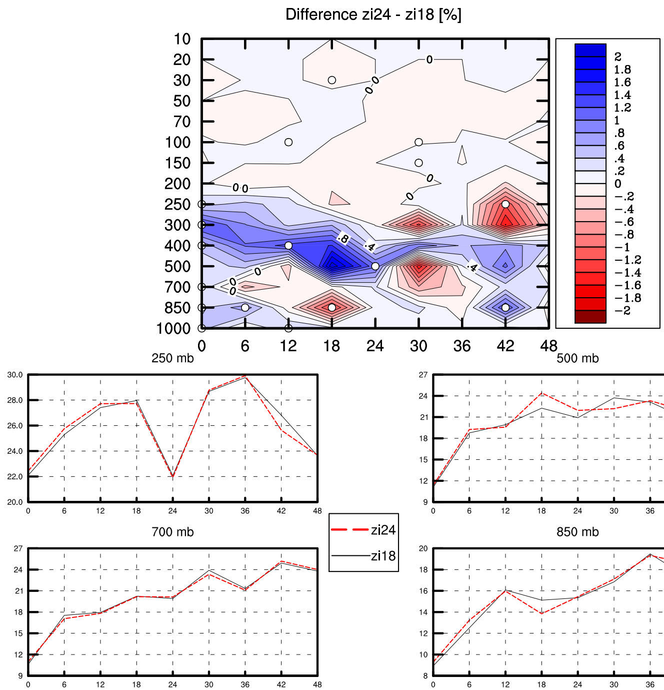
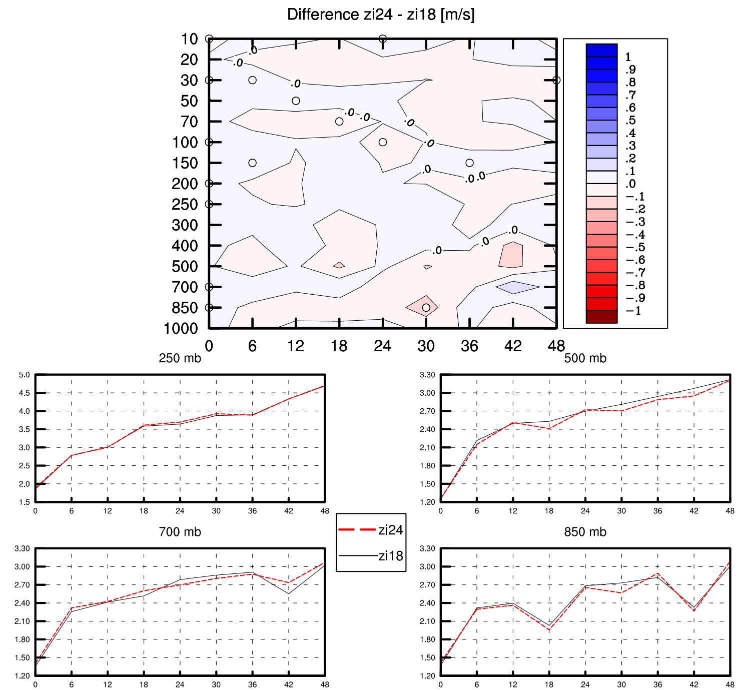
Figure 7: RMSE of experiment with assimilation cycle (zi24) compared to reference experiment (zi18). Verification was done against TEMP observations. Small circles show statistically significant difference.

(a) Relative humidity



(b) Wind speed



Performance Full obs 3

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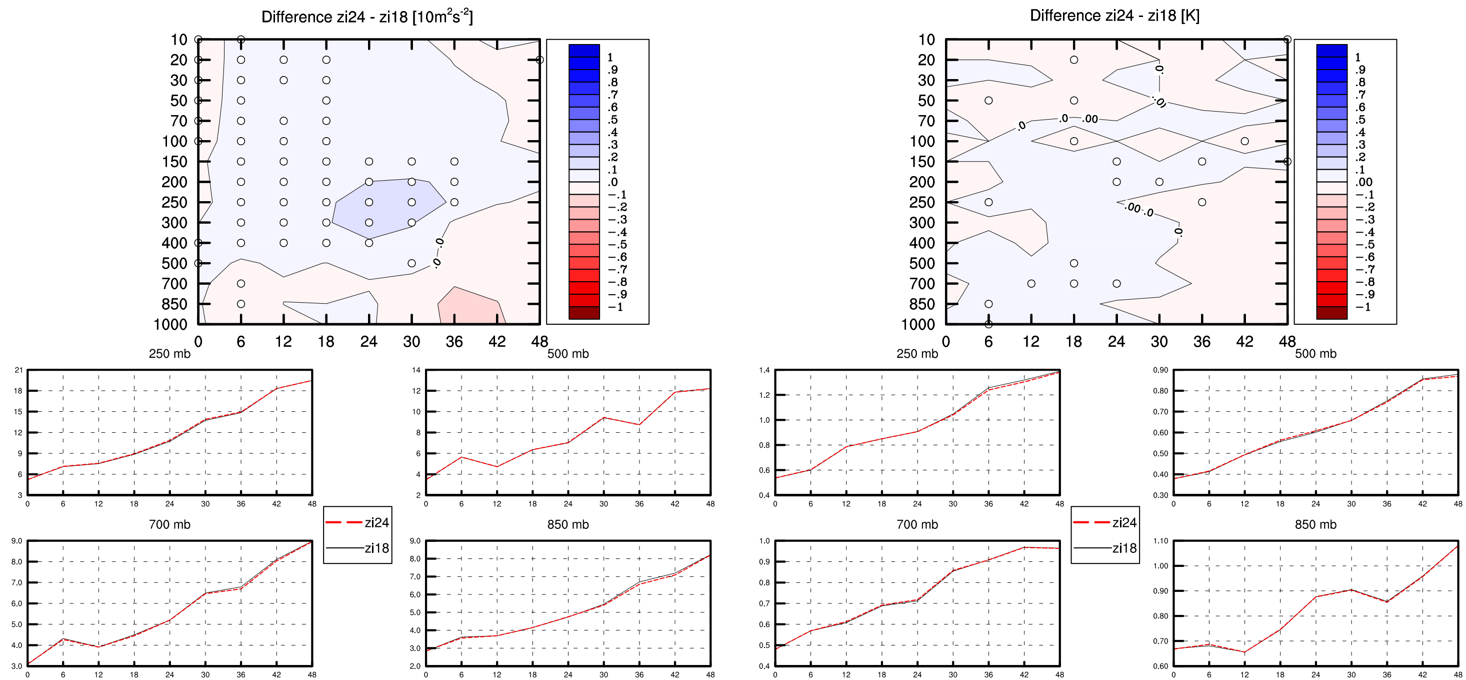
Figure 8: RMSE of experiment with assimilation cycle (zi24) compared to reference experiment (zi18). Verification was done against ECMWF analyses. Small circles show statistically significant difference.

(a) Geopotential **(b)** Temperature



Performance Full obs 4

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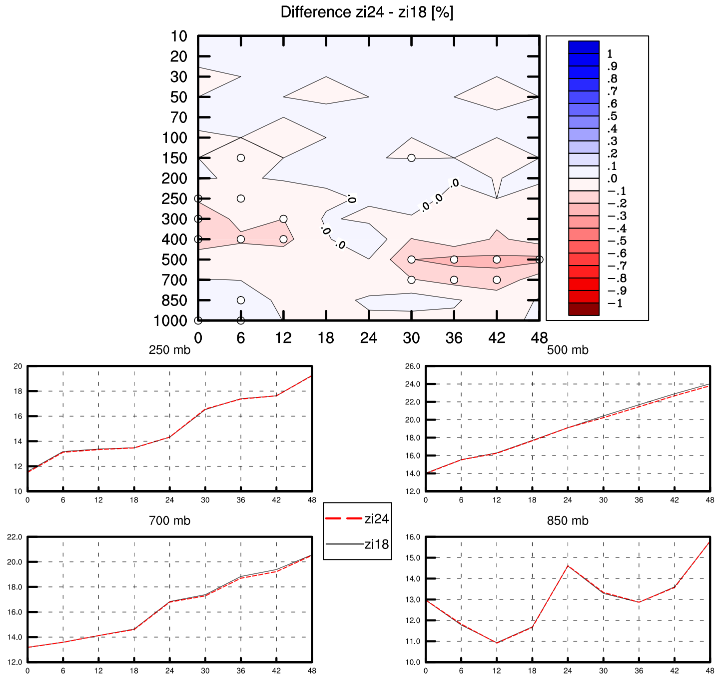
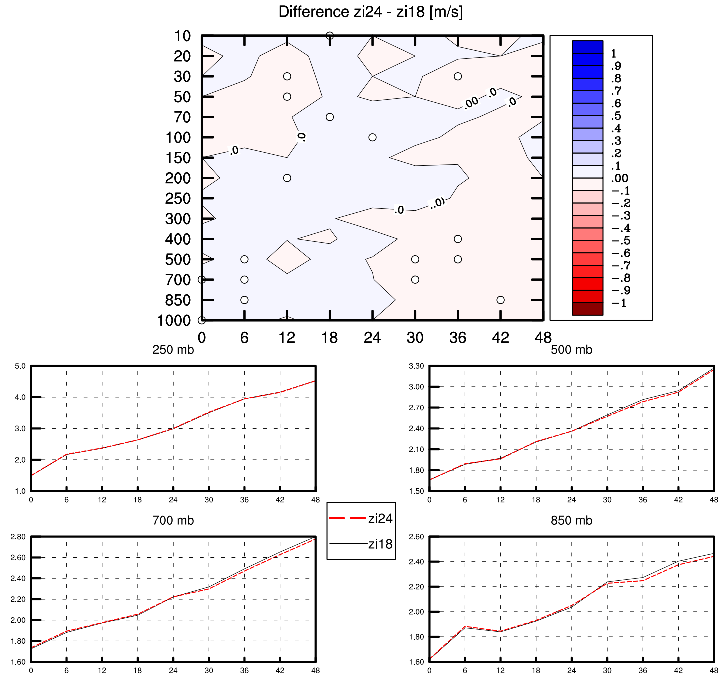
Figure 9: RMSE of experiment with assimilation cycle (zi24) compared to reference experiment (zi18). Verification was done against ECMWF analyses. Small circles show statistically significant difference.

(a) Relative humidity



(b) Wind speed



Performance Full obs 5

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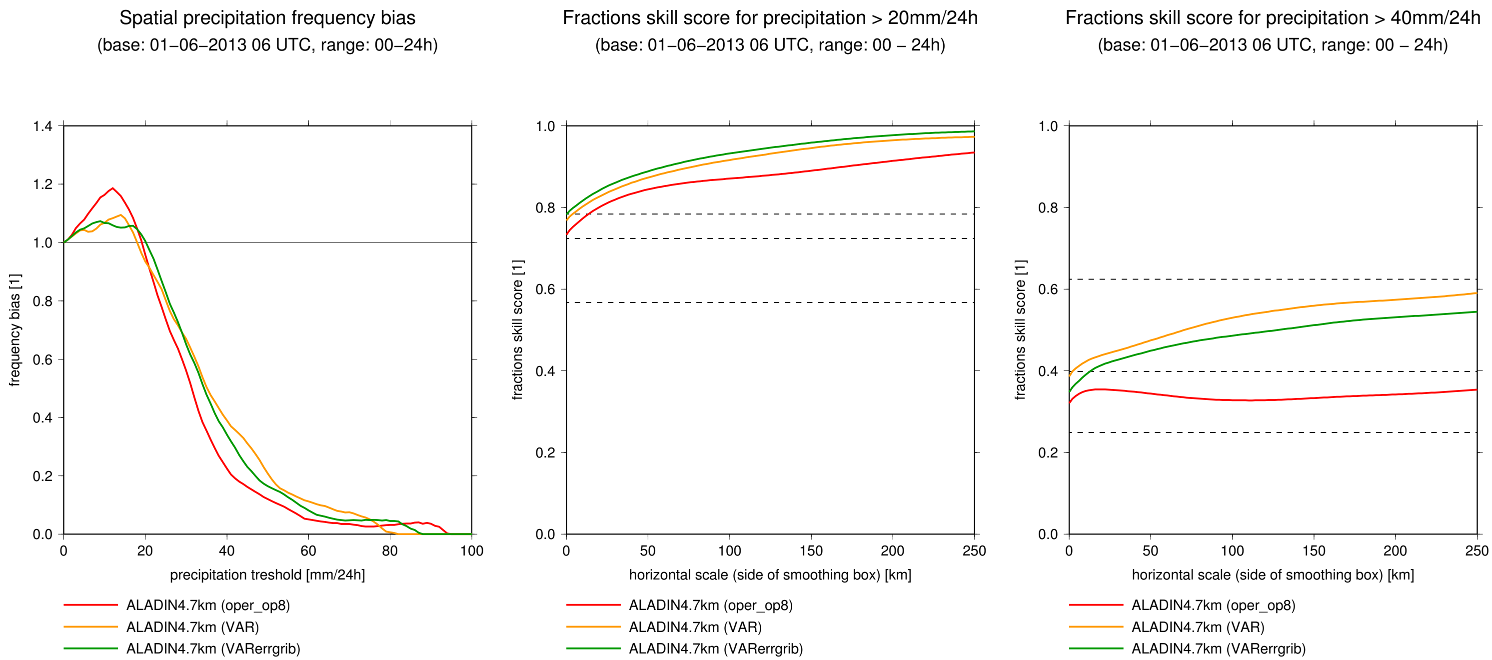
Figure 10: Frequency bias and fraction skill score for forecast on 1.6.2013 06 UTC, VAR denotes reference experiment (zi18), VARerrgrib is experiment with sigma_b maps (zi24) and oper_op8 is experiment with operational setup.



Potential problems

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- Use of humidity is not straightforward because humidity is uni-variate in AEARP.
- If humidity is missing in errgrib empirical formula for sigma_b is used instead!
- There is bug for key LCFCE=.T.
- Division by map factor is done at the end of suinfce.F90 instead of beginning before all computation is done!

Arome Bug

- Problem appears when humidity is held in grid-point space and LSFPCE=.F. (Sigma_b maps are used).
- Humidity behaves as uni-variate because balance computation is held in spectral space and appropriate buffer SPJB is not filled with humidity field.
- I propose to adapt routines jbtomodel.F90 and jbtomodelad.F90 in which humidity needs be transformed to spectral space and filled to "SPJB" buffer.
- Repaired versions of these routines for cycle 36 could be found on RCLACE forum:
  http://www.rclace.eu/forum/viewtopic.php?f=30&t=365

Local generation of sigma_b maps

- Benjamin Menetrier has written article about sigma_bs in Arome (RMETS 2014)
- It will be necessary to adapt at least SUJBVARENS, SUJBCOVNOISE, SUJBCOVSIGNAL, FLTBGCALC, reading of ensemble members and writing of errgrib
- I was promised by MF, they will provide the code in Autumn this year

SIGMAO_COEF

- There is a bug in CY38T1 defrun.F90! Correction could be found on RCLACE forum.

```
!*             2.6   Modification of sigmaos with coefficient
   SIGMAO_COEF

WRITE(CLFMT,FMT="('('' SIGMAO_COEF(1:',I2,') ='',',I2,'F8.3)')")
   JPNOTP,JPNOTP
WRITE(NULOUT,FMT=CLFMT) SIGMAO_COEF(:)
IF(.NOT.LECMWF)THEN
  ROERR_RAD1C(:,:)=ROERR_RAD1C(:,:) * SIGMAO_COEF(NSATEM)
  RBGQC(:,:,:)=RBGQC(:,:,:) / (SIGMAO_COEF(NSATEM)*SIGMAO_COEF(
     NSATEM))
  RBGQC_RAD1C(:,:,:)=RBGQC_RAD1C(:,:,:) / (SIGMAO_COEF(NSATEM)*
     SIGMAO_COEF(NSATEM))
  ROERR_QSCAT = ROERR_QSCAT * SIGMAO_COEF(NSCATT)
ENDIF
```

SIGMAO_COEF

- **Bugfix**

```
!*              2.6    Modification of sigmaos with coefficient
   SIGMAO_COEF

WRITE(CLFMT,FMT="('(''  SIGMAO_COEF(1:',I2,') ='',',I2,'F8.3)')")
   JPNOTP,JPNOTP
WRITE(NULOUT,FMT=CLFMT) SIGMAO_COEF(:)
IF(.NOT.LECMWF)THEN
    ROERR_RAD1C(:,:)=ROERR_RAD1C(:,:) * SIGMAO_COEF(NSATEM)
    DO  JOBT=1,JPNOTP
      RBGQC(:,JOBT,:)=RBGQC(:,JOBT,:) / (SIGMAO_COEF(JOBT)*
         SIGMAO_COEF(JOBT))
    ENDDO
    RBGQC_RAD1C(:,:,:)=RBGQC_RAD1C(:,:,:) /(SIGMAO_COEF(NSATEM)*
       SIGMAO_COEF(NSATEM))
    ROERR_QSCAT = ROERR_QSCAT * SIGMAO_COEF(NSCATT)
ENDIF
```

SIGMAO_COEF 2

- **Not every variable is multiplied by SIGMAO_COEF in bator (or screening)!**
- **RBGQC (here denoted as n) is divided by SIGMAO_COEF (sio) in defrun.F90**
- **according to manual[1] first guess check makes observation suspicious if:**

$$(O-F)^2 > n\left({\sigma_o}^2 + {\sigma_b}^2\right) \tag{9}$$

- **but due to defrun.F90:**

$$(O-F)^2 > \frac{n}{sio^2}\left({\sigma_o}^2 + {\sigma_b}^2\right) \tag{10}$$

- **if one wants to avoid SIGMAO_COEF in first guess check the equation should look like:**

$$(O-F)^2 > n\left(\frac{{\sigma_o}^2}{sio^2} + {\sigma_b}^2\right) \tag{11}$$

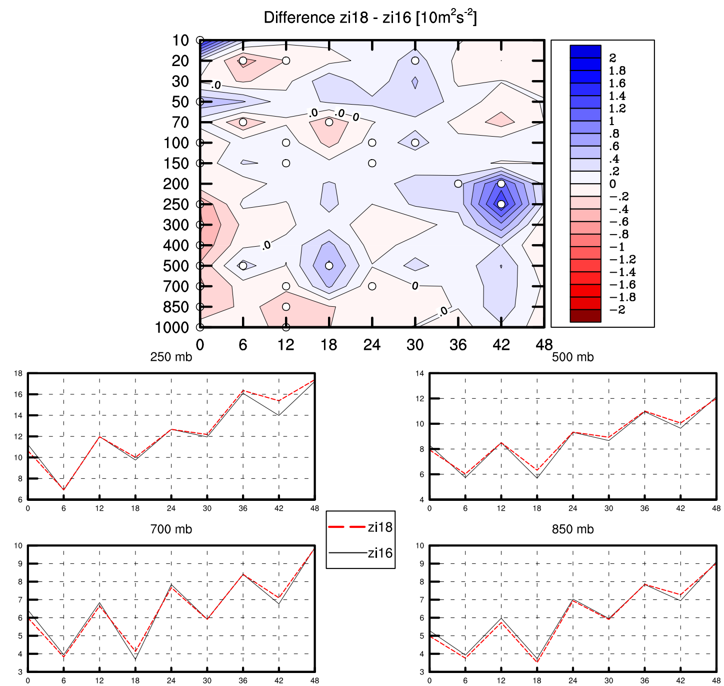
- **Does anyone understand the reason for division RBGQC by SIGMAO_COEF?**

[1] http://www.cnrm.meteo.fr/gmapdoc/spip.php?article11 page 22

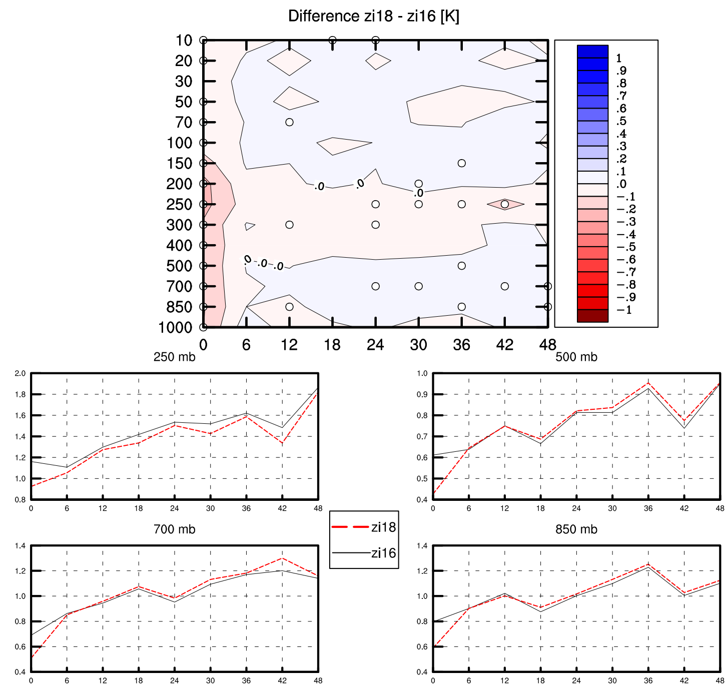
Floods case study

Figure 11: RMSE of experiment with with 3DVAR compared to operational setup (zi16). Verification was done against TEMP observations. Small circles show statistically significant difference.

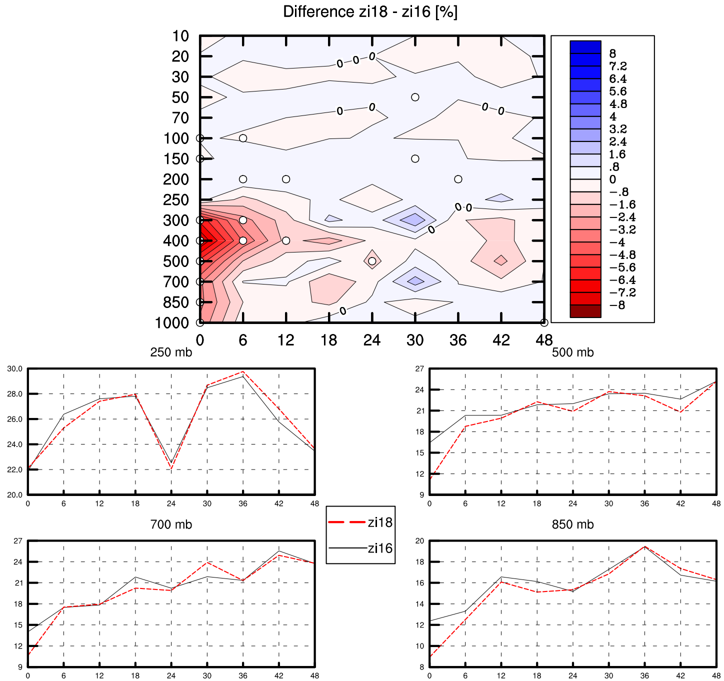
(a) Geopotential



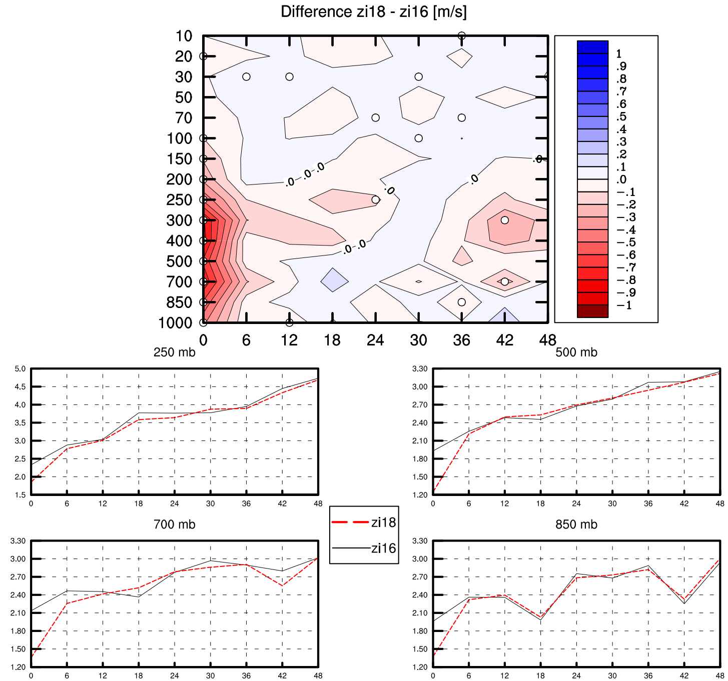
(b) Temperature



Floods case study 2



(a) Relative humidity

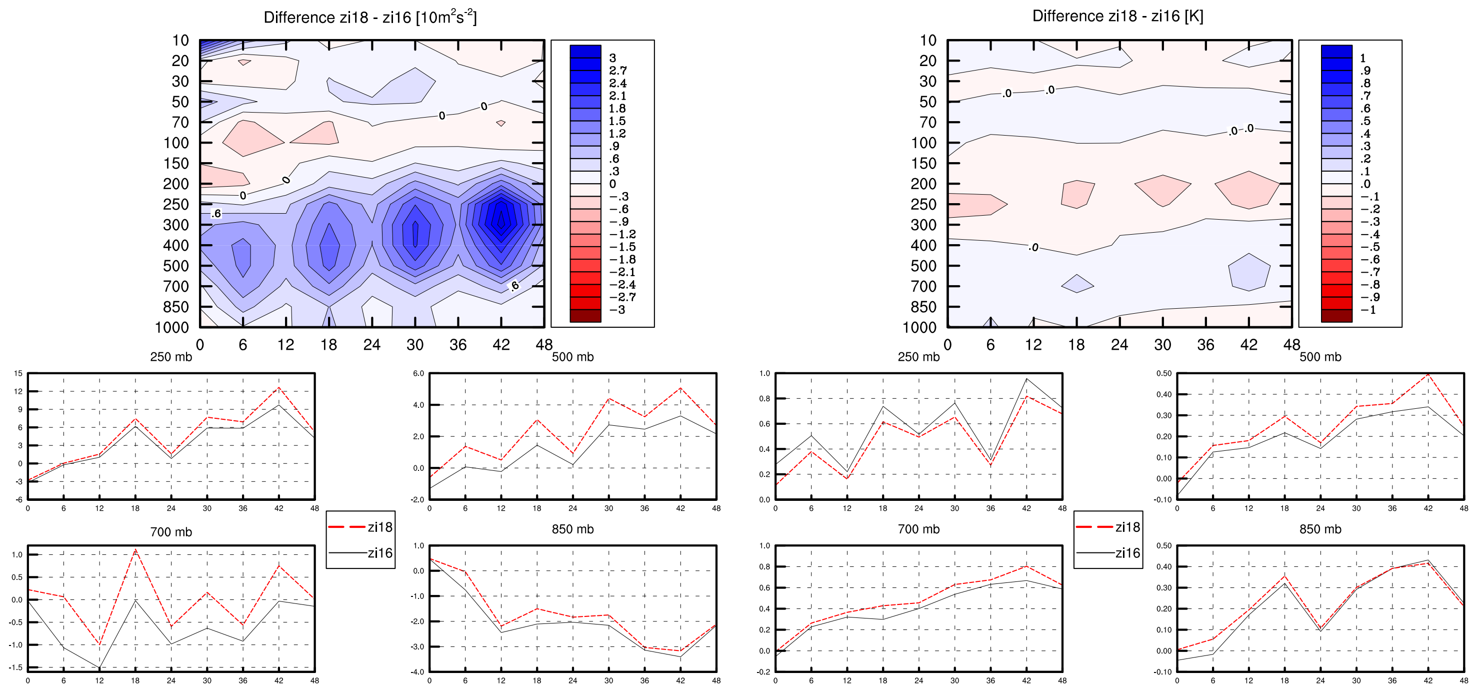


(b) Wind speed

Floods case study 3

Figure 13: BIAS of experiment with with 3DVAR compared to operational setup (zi16). Verification was done against TEMP observations. Small circles show statistically significant difference.

(a) Geopotential **(b)** Temperature



Floods case study 4

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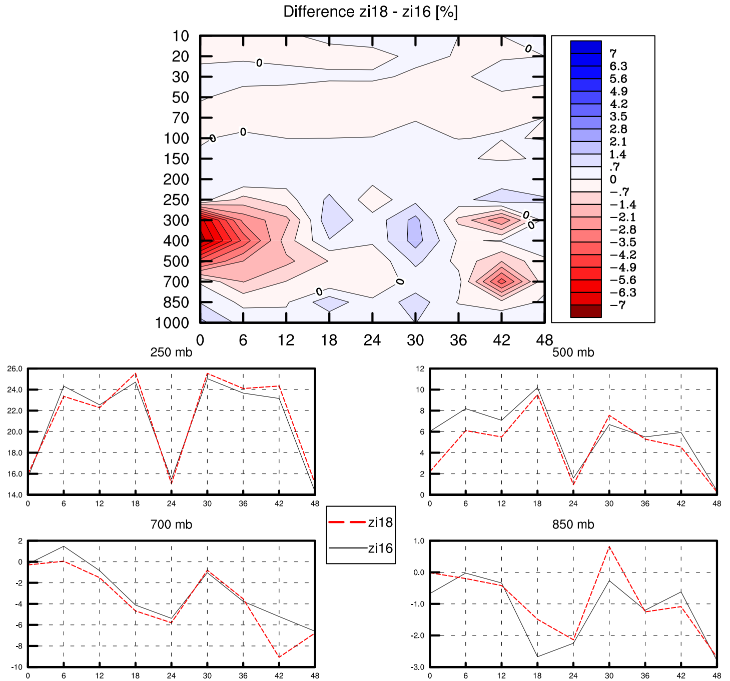
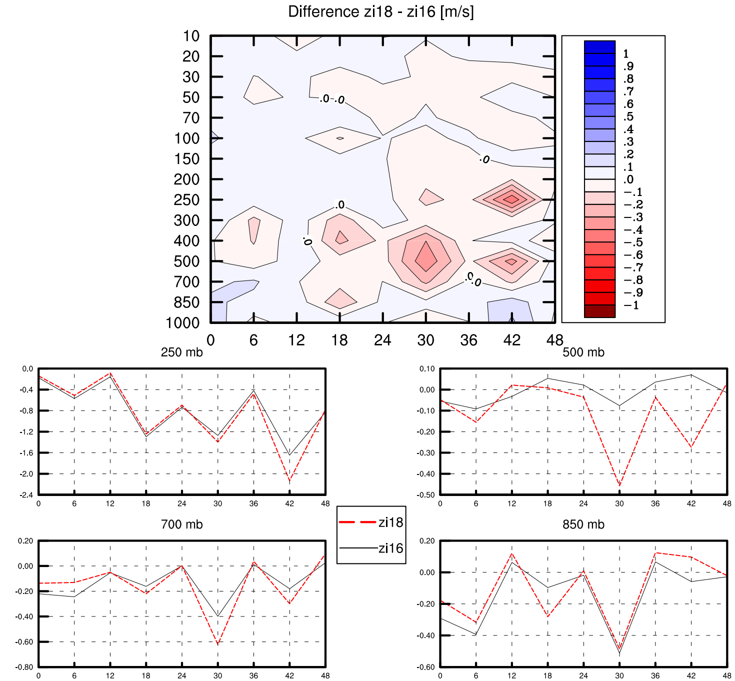


(a) Relative humidity



(b) Wind speed

Floods case study 5

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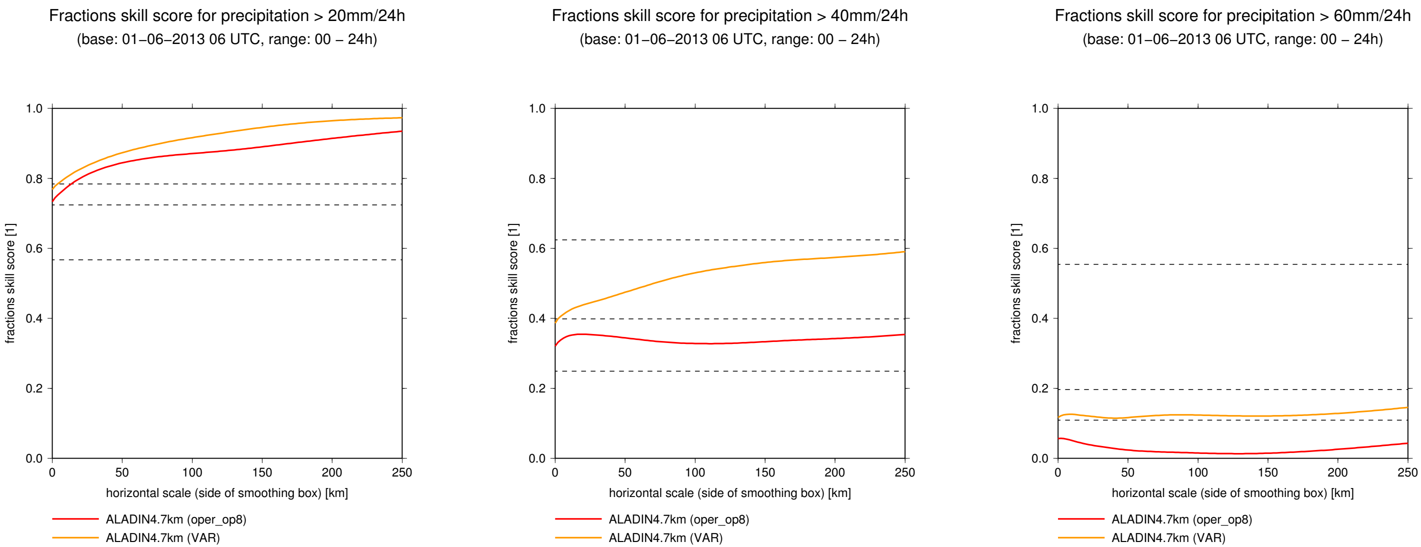
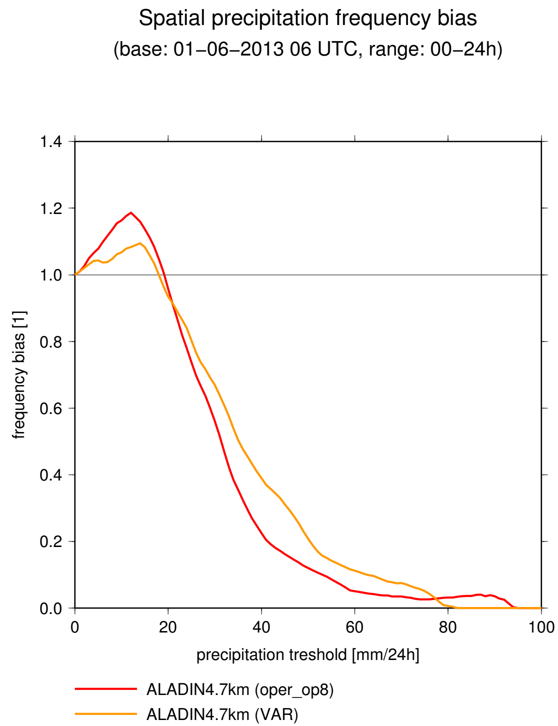
Figure 15: Fraction skill scores, experiment zi18 here referred as VAR is better for all tested tresholds.



Floods case study 6

Figure 16: Frequency bias, experiment zi18 (VAR) has slightly better distribution of precipitation.



Operational Setup

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- ALARO-0 baseline CY38T1_bf03
- Δx ~4.7km, 529x421 grid points, linear truncation E269x215,
- 87 vertical levels, mean orography,
- 6h cycling, time step 180s, 3h coupling interval,
- surface CANARI + Blending (filtering truncation E87x69),
- production 4 times a day (00 06 12 18 UTC) up to +54h

Near future

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- By the beginning of 2015 we would like to start 3DVAR operational parsuite
- production 4 times a day (00 06 12 18 UTC) up to +54h
- We will put 3DVAR on top of blending
- Planned observation: SYNOP, TEMP, AMDAR, AMV, MSG
- 3h assimilation window
- tuning: SIGMAO_COEF=0.67 REDNMC=1.7

Thank You for Your attention !