
3dVar Exercises

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Exercises part 1: 3dVar

- Choose the starting settings for the 3dVar part:
 - ▶ `type opt.which = "3",`
 - ▶ `opt.obsloc = 1:40.`
 - ▶ `opt.obserr = 0.54.`
 - ▶ In the script, set `ens_B = 0`, `b_inf = 1.0` and execute `run95.sce`.
 - ▶ start the run with `run95(500,opt)`
- After the program has finished, it displays the RMSE of the free forecast, the RMSE of the 3dVar (background and analysis) and two other values which will be discussed next.

Exercises part 1: 3dVar

- In the 3dVar, it is important to use an appropriate **B** matrix. A simple method to check if this is the case is to use a method proposed by Desroziers et al. (*Q.J.R. Meteorol. Soc* (2005), **131**, 3385-3396):

$$\mathbf{d}_b^a (\mathbf{d}_b^o)^T = \mathbf{HBH}^T$$

where \mathbf{d}_b^a is the difference between background and analysis, \mathbf{d}_b^o that between background and observations and \mathbf{HBH}^T is the background covariance matrix; all quantities are taken in observation space. This equation allows to estimate whether the entries of **B** are too large or too small. The value printed as "Avg. estim. infl. fac. 3dVAR" is the result of this equation.

- to check our results, we can estimate the analysis error from theory by $a = \sqrt{\frac{1}{\frac{1}{b} + \frac{1}{r}}}$ where a is the analysis error, b the background variance and r the observation variance. This equation can only be applied in spatial and temporal homogenous systems which is the case with the current settings. "estim. ana. err. 3dVAR" is the result of this equation.

Exercises part 1: 3dVar

- The standard **B** matrix used (`B6h1.r8`) has been obtained for the settings chosen above. What can you say about the results - RMSE error of background/analysis, and the estimated inflation factor? Compare the estimated analysis error with the actual one.
- We now change the observation error by `opt.obserr = 1` and running the simulation by `run95(500,opt)`. What is the effect on the RMSE? Again compare the estimated and the actual analysis error.
- Now use the estimated inflation factor from the last run by setting `b_inf` to this value, executing `run95.sce` and running the simulation again. How did the RMSE change? Interpret the estimated inflation factor and again compare the estimated analysis error with the actual one.

Exercises part 1: 3dVar

- We now reduce the number of observations, $N_{\text{obs}} = 20$. Type `opt.obsloc=1:2:40`. Reset `b_inf` to 1. Can you again use the estimated `b_inf` to reduce the RMSE? Is the above equation for the estimation of the analysis RMSE still correct?
- next we choose a inhomogenous observation system: only gridpoints 1 to 20 are observed. Type `opt.obsloc=1:20` and reset `b_inf=1.0`. What are the results?
- again try to obtain better results by tuning the **B** matrix with the estimated inflation factor.

Exercises part 1: 3dVar

- Up to now, we have used a homogenous \mathbf{B} matrix which is appropriate for a homogenous observation system. Changes in the observation error can be accounted for by tuning the matrix with a scalar inflation factor. In the case with only the first 20 gridpoints being observed this is not true anymore. Thus we will now use a \mathbf{B} matrix generated by a LETKF (averaged over many cycles).
- set `ens_B` to 1, now the \mathbf{B} matrix estimated with LETKF (`B_letkf.r8`) will be used. Reset `b_inf=1.0`.
- Compare the results with that from the tuned homogenous \mathbf{B} matrix.
- Note that it is not possible to use the estimated inflation factor to further tune the ensemble generated \mathbf{B} matrix as the latter is inhomogenous now and thus a scalar tuning factor is not appropriate.
- However, you can try what happens if you use the estimated inflation factor.

Exercises part 1: 3dVar

- Now, we want to have a look at both **B** matrices.
- type `opt.B = 1`. Now a second window appears where the **B** matrix is plotted. Rerun the simulation with `ens_B = 1` and `ens_B = 0`.

