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# *Interactive comment on* "A variational data assimilation system for soil–atmosphere flux estimates for the Community Land Model (CLM3.5)" *by* C. M. Hoppe et al.

**C. M. Hoppe et al.**

c.hoppe@fz-juelich.de

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We are very grateful to both referees for their valuable suggestions and questions, which substantially helped to improve our manuscript. Please find below our responses to Referee 1:

1. Page 6611, equation (1): I suggest to insert a subscript i to both the observation operator H and the observation error covariance R and modify subsequent references to H and R accordingly. In the paragraph following eq. (1), explain that B is a representation in the data assimilation system of the (unknown) background error covariance matrix. Insert also a brief justification of why in the present study B has been speci-



fied as diagonal. It is well-recognized that proper specification of the background error statistics is a major issue in 4D-Var. See also recent efforts on hybrid ensemble/4D-Var data assimilation at NWP centers.

Answer: The subscript i will be added to the observation operator H and the observation error covariance R.

We thank the reviewer for the remark concerning the matrix **B**, particularly since we noticed that our description of **B** was not accurate. In fact, the description of the covariance formulation is written for an older version and the set-up of this study includes off-diagonal non-zero elements of the background (forecast) error covariance matrix **B** . Details are revealed below in the paragraph included. We deleted the sentence with the diagonal **B** and replaced it by the following section:

In this study, **B** includes the vertical correlation, while cross-covariances between temperature and humidity are not taken into account. With these two parameters and 10 soil layers, **B** is a symmetric $20 \times 20$ two-block diagonal matrix, which can be factorised in a $\Sigma$ diagonal matrix of standard deviations and a correlation matrix **C** to read $\mathbf{B} = \Sigma\mathbf{C}\Sigma$. We assume that the vertical correlation increases with depth, following the same reasoning which designs the vertical grid spacing to increase with depths. Therefore, we argue that the variable layer thickness can be taken as units. Adopting a Gaussian covariance model for the correlation, dependent on distance in terms of model layer units, elements of $\mathbf{C}$ then read

$$C_{ij} = \exp\left(-\frac{1}{2}\frac{(i-j)^2}{l^2}\right). \tag{1}$$

Here $i$ and $j$ are the soil layer indices, and $l$ is the correlation length in terms of layers. In our case we found best results with $l = 2$.

2. Equation (2): there should be no summation on the first term (Jb x0-gradient)

Answer: This will be corrected. The summation on the first term will be deleted.

3. Page 6612:20 I don't get what this means $M_i* := H'T$. It should be $M_i* := M_i'T$. Also, boldface fonts should be used for $M_i'$ and its adjoint.

Answer: This will be corrected as suggested by the reviewer.

4. Section 3.2.1 on validation of the adjoint code should be substantiated by incorporating the numerical outcomes from the validation tests. Otherwise, this section has no significance, as all the material presented here is standard.

Answer: We agree with the reviewer. We missed to include the practical outcome of the tests. We included in the text the following paragraph, which concludes the subsection:

The advantage of the tangent linear method is that the equivalence of the adjoint and tangent linear can be validated exactly. On the other hand, there is still the problem that the automatic differentiation tool may engender the same error for both calculations. In our case, we used TAPENADE as adjoint and tangent linear compiler. We also applied the finite difference method for validation. Applying both the finite difference method and the tangent-linear method, it could be verified that our adjoint code development of the core of CLM is correct. In more detail, it came out that there is less difference than 1 per mille between the exact tangent linear and the difference method if the choice of $\delta x$ is appropriate. In case of the CLM plant respiration, it was found by this double checking procedure, that the highest TAPENADE optimisation level gave erroneous results. In reducing the optimisation, the correctness of the code could be directly proven.

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Interactive comment on Geosci. Model Dev. Discuss., 6, 6605, 2013.