Nonlin. Processes Geophys. Discuss., 2, C496–C501, 2015
www.nonlin-processes-geophys-discuss.net/2/C496/2015/

Nonlinear Processes
in Geophysics
Discussions
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Interactive comment on "Diagnosing non-Gaussianity of forecast and analysis errors in a convective scale model" *by* R. Legrand et al.

R. Legrand et al.

raphael.legrand@meteo.fr

Received and published: 23 October 2015

Dear Referee,

Thank you for those questions and comments. Please find below, our answers and the associated changes added to the manuscript.

Best regards,

Raphaël Legrand, Yann Michel and Thibaut Montmerle

(Reviewer comments are written in black, and authors answers are in blue)

Specific comments:

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Comments from Referee→(1) p.1072, L.5-9: what is the implication of small K^2 in the regions of large ensemble forecast variance? Could you elaborate in more detail?
Author's response→ Having small K^2 values implies that according to our diagnostics, background errors are sampled from a Gaussian distribution, which is consistent with the hypothesis of Gaussianity made in our data assimilation system. Additionally, in presence of large background error variances, the background is assumed to be less reliable and more weight should be put on observations in that area during the analysis.
Author's changes in manuscript→ None.

Comments from Referee→(2) p.1075 (section 4.2.1): Could you further elaborate on vorticity and divergence control variables and the possible reasons for their non-Gaussian behaviour. Is it possible that this is related to their definition as second derivatives of stream function and velocity potential, both commonly used as Gaussian? Would this suggest it may be better to use stream function and velocity potential as control variables in order to stay within the Gaussian framework?
Author's response→The first or second order derivation use linear operators. So theoretically the derivative of an initially Gaussian distribution, is also Gaussian. We suspect however that derivation of a nearly-Gaussian process may indeed increase its NG. Furthermore another possible source of NG has been highlighted by the second reviewer: the heteroscedasticity (spatial variability of the variance) of the wind fields.
To go further on this topic, NG diagnostics have been computed for the temperature T, which is a nearly Gaussian field (cf Fig. 3a), for the temperature normalized by its standard deviation $\frac{T}{\sigma_T}$, and for their respective first-order spatial derivatives ($\frac{\partial T}{\partial x}$ and $\frac{\partial \frac{T}{\sigma_T}}{\partial x}$). Results are gathered in the attached new figure (Fig.1 of the comment) giving vertical profiles of K^2 for T (solid black line), $\frac{T}{\sigma_T}$ (dashed red line), $\frac{\partial T}{\partial x}$ (dotted blue line), and

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$\frac{\partial \frac{T}{\sigma_T}}{\partial x}$ (dot-and-dash green line). For each level, values are averaged over the horizontal domain. Profiles have been computed from a 90-members ensemble of 3h-forecasts valid the 4^{th} of November 2011 at 03:00. Three conclusions arise from this experiment:

- the profiles of T and $\frac{T}{\sigma_T}$ are almost equal (differences smaller than 0.01). This supports the fact that NG diagnostics for a particular parameter do not depend on its variance.
- the large increase of K^2 between fields (normalized or not) and their derivative seems to support the fact that derivation of a nearly Gaussian variable increases its NG. Moreover, despite the use of T instead of one of the wind components, the order of magnitude of the NG is close to the one found in Fig.9(a) and Fig.10 for the vorticity and the divergence, which support the attribution to derivation for at least a part of their NG.
- differences of NG between $\frac{\partial T}{\partial x}$ and $\frac{\partial \frac{T}{\sigma_T}}{\partial x}$ enable to know more about the impact of heteroscedasticity. It seems that the homogenization (all variances set to 1 with the normalization) yields a systematic decrease of NG for every model levels yet very small compare to the increase implied by the spatial derivation.

Those conclusions are in accordance with the large NG of ζ and η which are defined as spatial first order derivatives of the largely Gaussian wind fields.
Considering those results, the couple stream function/velocity potential should display more Gaussian behaviour than ζ/η, which would make them good candidates for being the dynamical control variable. (as in the Met Office assimilation system for instance). Future work is however still needed to confirm this point.
Author's changes in manuscript→ Added in section 4.2.1: "To go further on this topic, NG diagnostics have been computed for the spatial first-order derivative of T. While T

is a nearly Gaussian variable (see Fig.3a), its spatial derivation largely increases the NG (not shown), up to the order of magnitude found in Fig.9a and Fig.10 for ζ and η. This supports the attribution to derivation for at least a part of the NG displayed for the dynamical control variables.".

Technical corrections:

Comments from Referee→(3) p.1063, L.13: Delete “Of course”, start sentence with “In general ...”. Substitute “will lead” by “could lead”, unless there is a reference stating that. In that case include the reference.
Author’s response→We agree with this correction
Author’s changes in manuscript→ Changed in the introduction: "The time integration of the model nonlinear dynamics leads inevitably to non-Gaussian forecast errors (Bocquet et al., 2010).".

Comments from Referee→(4) Figs.3, 6, 8, 9, and 10: It is difficult to distinguish between the dotted and dashed lines. Would it be possible to recreate this figure with more distinct lines? Also, please include in the figure caption the description of lines (e.g., dashed, dotted, full,. . .).
Author’s response→We agree with this correction
Author’s changes in manuscript→Figs.3, 6, 8, 9, and 10 have been recreated with clearer line settings and colors. Moreover Fig6(c) has been simplified. Lines descriptions are retrieved in legends on top of each figure, in order to keep the captions as synthetic as possible.

References

Bocquet, M., Pires, C. A., and Wu, L.: Beyond Gaussian statistical modeling in geophysical data assimilation, Mon. Weather Rev., 138, 2997–3023, 2010.

Interactive comment on Nonlin. Processes Geophys. Discuss., 2, 1061, 2015.

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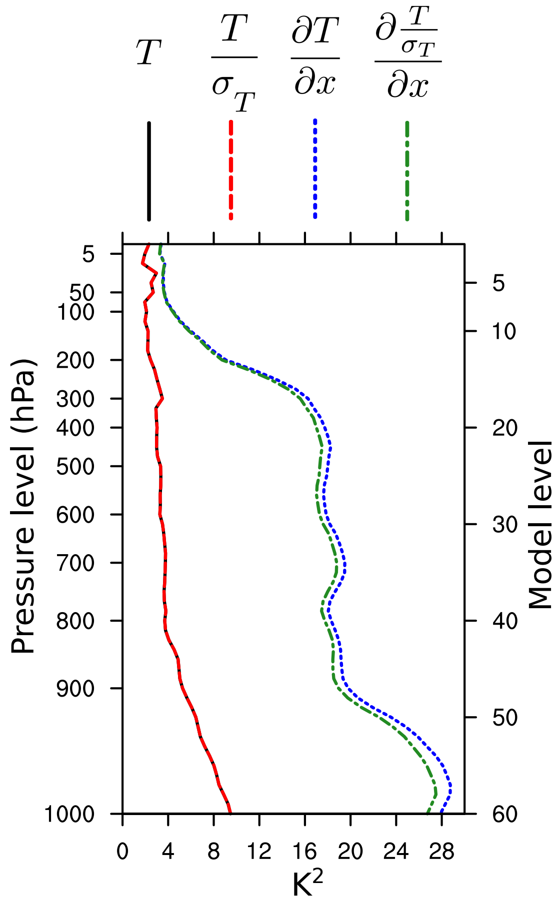

Fig. 1. Vertical profiles of K2 for T, normalized T, and for their respective first-order spatial derivatives (see text).

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