Nonlin. Processes Geophys. Discuss., 2, C502–C509, 2015
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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.

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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)

Comments from Referee→(1) The transformed estimator $f_4(G_4)$ for kurtosis was

originally presented by Anscombe and Glynn(1983), after that of d'Agostino (1970) test for skewness. The omnibus test (4) in pg. 1068 was presented by D'Agostino et al. (1990). See refer- ences bellow and add to manuscript. Anscombe, F.J.; Glynn, William J. (1983). "Distribution of the kurtosis statistic b2 for normal statistics". Biometrika 70 (1): 227–234. doi:10.1093/biomet/70.1.227. JSTOR 2335960 D'Agostino, Ralph B.; Albert Belanger; Ralph B. D'Agostino, Jr (1990). "A suggestion for using powerful and informative tests of normality" (PDF). The American Statistician 44 (4): 316–321.doi:10.2307/2684359. JSTOR 2684359.
Author's response→We agree with this point.
Author's changes in manuscript→ The two references (Anscombe and Glynn, 1983; D'agostino et al., 1990) have been added, and the K^2 is now rightly attributed to D'agostino et al. (1990) instead of D'Agostino (1970).

Comments from Referee→(2) Beyond K^2 (Eq. 4), other diagnostics of NG have been used on assimilation error and innovation diagnostics, like those relying cumulant-based expansions of the negentropy or the Kullback-Leibler divergence with respect to the fitting Gaussian pdf (Pires et al. 2010). Add the reference: Pires, C.A., O. Talagrand, M. Bocquet, 2010. Diagnosis and Impacts of non- Gaussianity of Innovations in Data Assimilation. Physica D. Nonlinear Phenomena, Vol. 239, (17), 1701-1717. doi:10.1016/j.physd.2010.05.006
Author's response→We agree with this point.
Author's changes in manuscript→References to kullback (1959), and Pires et al. (2010) have been added.

Comments from Referee→(3)- Fig 3b and 3c present profiles of the horizontal averages of f_3 and f_4 for humidity. However local values of f_3 and f_4 may exhibit quite larger and extreme values (see Figs 4b and 4c) than their horizontal averages. Figs 3b and 3c do not give an idea of the NG range over the area. A figure with profiles

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showing the range interval (e.g. 5-95%) of f_3 and f_4 would be useful. It would be more consistent with Fig 3a presenting spatial averages of the local K^2 values.

Author's response→Thank you for this remark. The description of the spatial variability of the NG diagnostics was indeed insufficient, and discussion of ranges for K^2, $f_3(G_3)$ and $f_4(G_4)$ has been added in the section 3.3 of the manuscript. This description is based on results displayed in Fig.1 below (caption: Vertical profiles of ranges of **(a)** K^2, **(b)** transformed skewness $f_3(G_3)$, **(c)** transformed kurtosis $f_4(G_4)$. Profiles are computed from the 90-members ensemble of AROME-France 3h-forecasts valid at 03:00 UTC the 4 November 2011. Profiles are given for four model variables: U, V, T, and q.), which is not included in the text since many similarities have been found between parameters and materials that are already present in the article.

Author's changes in manuscript→ Added in section 3.3: "The range, defined as the difference between the 95th and the 5th percentiles, could be used to describe roughly the horizontal spatial variability for each vertical level. Vertical profiles of ranges of K^2, $f_3(G_3)$, and $f_4(G_4)$ (not shown) have, all three, large similarities between each other, and with the shapes of K^2 profiles displayed in Fig3(a). It includes in particular two maxima in the boundary layer and in high troposphere for q and larger values towards the surface for T. Ranges are much larger for the four variables (approximately four times as large) than the respective mean values given in Fig.3, implying a large spatial variability for the three NG diagnostics. An example of the horizontal structures of NG is given for q in the boundary layer by Fig.4. They have large similarities with the meteorological coherent structures, as the Southerly convergent flow over South of France and the active cold front aloft North-West of France are associated with high values of K^2."

Comments from Referee→(4) - Pg 1071, line 15. Please be more rigorous not using the 'inversely proportional' attribute. For instance: larger values of K^2 generally occur for small values of q.

Author's response→We agree with this point.

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Author's changes in manuscript→It has been corrected as: "...K^2 is increasing while the q mean content, displayed in Fig.3(d), is largely decreasing.

Comments from Referee→(5)- Pg 1072, line 1. Negative skewness - left-tailed distributions. Please correct
Author's response→We agree with this point.
Author's changes in manuscript→It has been corrected

Comments from Referee→(6)- Pg. 1073. Relationships between NG and physical processes must be analysed with care. Which makes you to link diabatic processes to NG? NG can come from non-linear processes acting on Gaussian pdfs; linear processes acting on NG pdfs or both. Add a short justification.
Author's response→We agree that this study does not demonstrate that NG is caused by diabatic processes. It is true that NG may come from non-linear processes acting on Gaussian pdfs; linear processes acting on non-Gaussian pdfs or both. Yet we have shown that analysis errors have a more Gaussian behaviour in our system (e.g Fig.7 and Fig.8), such that NG in the background may rather come from non-linear processes acting on a nearly-Gaussian pdf. Also, we point out diabatic processes as a reasonable explanation based on Fig.6 that shows increased NG in cloudy conditions compared to clear sky ones.

A more extensive study of relations between physical processes and NG would require running ensembles with simplified physics, where some processes are turned off. This may be attempted in the future.
Author's changes in manuscript→Changes have been made in section 3.4: "During the 6 first hours of forecasts, NG quickly increases [...] Those results support that NG in the background may rather come from non-linear processes acting on nearly Gaussian pdfs instead of linear processes acting non-Gaussian pdfs." and then "For

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T and q, diabatic processes are good candidates to produce NG because of intrinsic thresholds in cloud physics (e.g. moisture saturation) and non-linear processes like turbulence on cloud-top."

Comments from Referee→(7) - Sec. 4.1 highlights the drastic reduction of NG of the analysis compared to that of background (Fig8a,b), specially over regions of dense radar observations. This can only be due to the hypothesis of Gaussianity of observation errors (e.g. radar) which is for the moment the better hypothesis to use. Comment that.

Author's response→The analysis increment is equal to a gain matrix times an innovation vector (observations minus background), i.e it is a linear function of the innovation in model space. Thus the Gaussianity of the analysis increment mainly depends on the Gaussianity of the innovations. Practically, innovations are close to Gaussianity thanks to a rough selection applied beforehand to the observations, allowing to remove outliers.

As regards radar data, a 1D+3D Var approach is used operationally for AROME (Caumont et al., 2010). It consists in retrieving profiles of relative humidity (RH) from observed reflectivities at first, and to consider such profiles as pseudo-observations in the 3D-Var (Wattrelot et al., 2014). Only small innovations of RH are kept in the process, insuring the Gaussianity of the corresponding innovations.

Author's changes in manuscript→Additional comment added in section 4.1: "The analysis increment being a linear function of the innovation vector in model space (observation minus background), its Gaussianity is insured by a rough selection applied beforehand to the observations, allowing to remove outliers (e.g. for radar data, Caumont et al., 2010; Wattrelot et al., 2014)."

Comments from Referee→(8) - Pg 1075. Despite the fact that vorticity and divergence

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are linear operators of the quasi Gaussian zonal and meridional wind fields, mostly of the NG comes from heteroscedasticidy (spatial variability of the wind variance). Refer this aspect

Author's response→This remark is similar to that made by reviewer 1 (and 2) in his second point. In order to study relative impact on NG of heteroscedasticity and spatial derivatives, 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 shown and explained in the answer to reviewer 1.

Author's changes in manuscript→Same as for reviewer 1.

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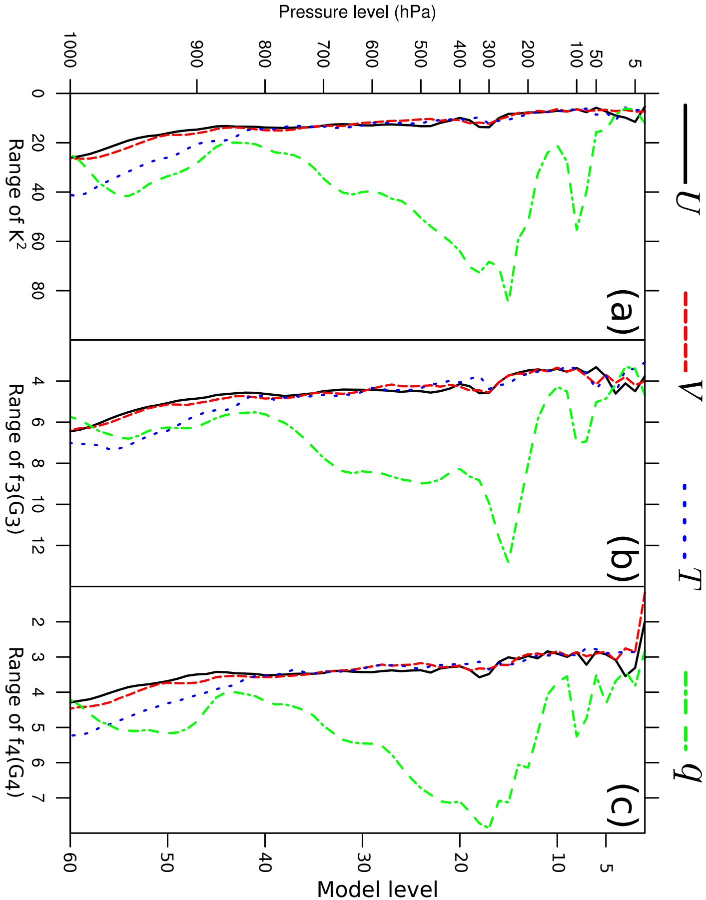

Fig. 1. Vertical profiles of ranges of (a) K2, (b) transformed skewness f3(G3), (c) transformed kurtosis f4(G4) (see text).

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