Dear Dr. Hella Garny,

On January 31, 2014, we received the comments from two anonymous referees on our submission (#GMD-2013-154) titled as "An improved Non-Iterative Surface Layer Flux Scheme for Atmospheric Stable Stratification Condition". The two reviewers both gave very positive assessments of our paper. We also made all necessary changes in order to address the reviewers' concerns and have detailed how the points raised by the reviewers have been accommodated. From the changes made in the revised manuscript and the responses provided by us, we hope you are convinced that we have adequately addressed the reviewers' concerns and made the paper stronger. After you make the decision, we will submit our revision to you for further assessment and consideration of publication in the journal, *Geoscientific Model Development (GMD)*.
I confirm that all authors listed on the manuscript concur with submission in its revised form. Should you have any questions, please feel free to let me know. Thank you very much for your efforts in evaluating our submission.

We would like to thank the two anonymous referees for reviewing our paper entitled "An improved non-iterative surface layer flux scheme for atmospheric stable stratification condition". The comments help us improve the manuscript significantly. Our detailed responses to the queries are below. Acknowledgments to the referees have been added in the manuscript.

Response to comments by Anonymous Referee #1

The authors present an algorithm to compute the stability parameter and the transfer coefficients in stable situations without the necessity to iterate. The method reduces the error of a recently proposed method (WRL12). I didn't go through the mathematical derivation of the equations but from the results provided the method seems to improve the accuracy of WRL12's method. This was the major goal of the work so I would recommend the paper for publication subjected to some minor comments provided below.

Response: We thank the reviewer for his/her positive assessment and recommendation.

A general comment that I would like to raise for discussion is whether we need such a complexity in our geophysical models to calculate the stability parameter and the transfer coefficients. The method proposed by WRL12 has already a large number of equations. The present one introduces a large number of parameters to fit the equations in the different regions (Table 2-8). Is this level of accuracy/complexity necessary given the large number of approximations that are already in our model's formulations? Any discussion in this direction would be desirable in the manuscript.

Response: We have added more discussion in section 5:

“The new equations involve a large number of parameters which increase the complexity of coding. However, the effort of coding the new scheme is minimal as compared to its potential gain, which includes the accuracy of the new scheme and the avoidance of iterations. Besides, a compromise can be made between accuracy and complexity. For models that are not interested in high kB^{-1} values, region 1 and 2 (i.e., $10 \le z / z_0 \le 10^5$ and $-0.607 \le z_0 / z_{0h} \le 100$) have provided reasonable coverage (see Garratt, 1992; Launiainen, 1995), and the other 6 regions can be ignored. For example, in WRF model MM5 surface module, $z_{0h} = z_0$ is assumed during the calculation of frictional velocity (Jimenez et al, 2012). While for models that include urban surface effects, it is better to keep all the regions. Further, CB05 probably is not the final solution for the surface flux calculation under stable stratification. The method used to derive non-iterative equations presented here can be used in future studies to transfer the new iterative algorithm to non-iterative equations.”

MINOR COMMENTS

1. It is not clear if the method only works for the stability range 0 < Ri < 2.5. If so this should be discussed since under stable conditions the winds are weak and often Ri is higher than 2.5.

Response: Yes, the new equations only work for the stability range $0 < Ri_B \le 2.5$. “Following WRL12, the condition that $Ri_B > 2.5$ is not considered in this study, because it represents extremely stable stratification with very weak wind and little flux exchange” is added in the Introduction section, page 6461, line 15.

2. It would be a good idea to describe a bit better the figures when they are presented in the text.

Response: Descriptions of figures have been modified in the text.

3. Adding a figure or sketch to clarify how the different regions are defined would make it easier to understand the method.

Response: The steps to the new equations are now summarized in section 3, as follows:

1) Divide z / z_0 into 13 sections: 10~20, 20~40, 40~80, …, 10240~20480, 20480~40960 and 40960~10^5; divide z_0 / z_{0h} in to 14 sections: 0.607~1, 1~10,

10~100, 100~10^3, 10^3~10^4, … , 10^{11}~10^{12} and 10^{12}~1.07×10^{13}.

2) Use the region $z/z_0 \in 10\sim20$ and $z_0/z_{0\mathrm{h}} \in 10^{12}\sim1.07\times10^{13}$ to find ζ_{c1}.

Method: when $\zeta \in 0\sim\zeta_{\mathrm{c1}}$, regression with Eq. (23) is kept within 5% error.

Result: $\zeta_{\mathrm{c1}}=0.33$ found.

3) Use $\zeta_{\mathrm{c1}}=0.33$ to recombine z/z_0 and $z_0/z_{0\mathrm{h}}$ sections defined in step 1.

Method: Variations of combinations of the 13 sections of z/z_0 and 14 sections of $z_0/z_{0\mathrm{h}}$ are tested to minimize the numbers of regions, and regression with Eq. (23) and $\zeta \in 0\sim0.33$ is kept within 5% error.

Result: 8 regions found (Table 1)

4) For each of the 8 regions, find $\zeta_{\mathrm{c1}}, \zeta_{\mathrm{c2}}$, …, ζ_{cp}, …

Method: when $\zeta \in 0\sim\zeta_{\mathrm{c1}}$, or $\zeta_{\mathrm{c1}}\sim\zeta_{\mathrm{c2}}$, …, or $\zeta_{\mathrm{c(p-1)}}\sim\zeta_{\mathrm{cp}}$, …, regression with Eq. (23) is kept within 5% error for $\zeta\le0.5$ and 10% error for $\zeta>0.5$.

Result: $\zeta_{\mathrm{c1}}, \zeta_{\mathrm{c2}}$, …, ζ_{cp}, …, for each region found

5) Transfer $\zeta_{\mathrm{c1}}, \zeta_{\mathrm{c2}}$, …, ζ_{cp}, …, to $Ri_{\mathrm{Bc1}}, Ri_{\mathrm{Bc2}}$, …, Ri_{Bcp}, …, with Eq. (24)

Method: for each region, when $Ri_{\mathrm{B}} \in 0\sim Ri_{\mathrm{Bc1}}$, or $Ri_{\mathrm{Bc1}}\sim Ri_{\mathrm{Bc2}}$, …, or $Ri_{\mathrm{Bc(p-1)}}\sim Ri_{\mathrm{Bcp}}$, …,regression with Eq. (23) is kept within 5% error for $\zeta\le0.5$ and10% error for $\zeta>0.5$.

Result: coefficients of Eq. (23) and Eq. (24) are derived.

Response to comments by Anonymous Referee #2

Summary:
In the study by Y. Li et al. an improved non-iterative parametrization for transfer coefficients for momentum and heat in the stable boundary layer (SBL) is presented. It is applicable for a wide range of aerodynamic and scalar roughness lengths including the effect of the roughness sublayer based on De Ridder (2010) approach. Authors use universal profile functions derived for SBL by Cheng and Brutsaert (2005). This paper further develops Wouters et al. (2012) approach and proposes a group of equations instead only one equation used in Wouters et al. (2012). I think that the study has the right to life and it is potentially a useful complementary to the literature in boundary layer parametrizations.

Recommendation:
The study proposed an updated parametrization scheme and manuscript is suitable for publication in the Geoscientific Model Development after some revision. My specific comments are listed below.

Response: We thank the reviewer for his/her review and recommendation.

General comments:
(i) Authors have preferred universal profile functions for SBL proposed by Cheng and Brutsaert (2005) derived from CASES-99 data. Although this choice is not in doubt, more discussion on the recent approaches in this field is needed in the paper than is currently provided. A number of important references on the profile functions in the SBL highly relevant to the current study were missed. First, detailed review of the different non-linear similarity functions based on data collected in a variety of conditions can be found in Sharan and Kumar (2011). In particular, Grachev et al. (2007) and Sanz Rodrigo and Anderson (2013) proposed flux-profile relationships based on the measurements in Arctic and Antarctic (over more flat surfaces than Kansas in CASES-99). Moreover, Sorbjan (2010) and Sorbjan and Grachev (2010) discussed an alternative local scaling for the SBL when different universal functions plotted versus the gradientRichardson number instead of the Monin-Obukhov stability parameter (gradient-based scaling).

(ii) Authors wrote on p. 6460 "However, the BD equation suppresses fluxes understable condition too quickly and is not applicable when the Richardson number exceedsa critical value (Louis, 1979)." Businger-Dyer (BD) relationships for the SBL areconsequence of MOST and they have the same limits of applicability as MOST. Theapplicability of the local MOST in the SBL is limited by inequalities, when both gradientand flux Richardson numbers are below their "critical values" about 0.20-0.25 (e.g.Grachev et al. 2013). Cheng and Brutsaert (2005), Grachev et al. (2007) among othersderived their parameterizations extending Monin-Obukhov formalism beyond thelimits of the MOST applicability. Although their parameterizations work for z/L »1,

theydon’t follow the classical Monin-Obukhov local z-less predictions (but BD relationshipsfollow). I think that this point should be clarified in the paper. In any case, parameterizationssimilar to Cheng and Brutsaert (2005) and Grachev et al. (2007) are not a finalsolution for the SBL.

Response: The references mentioned above have been added into the text. The applicability of MOST has been discussed in section 1, as follows:
“Based on the measurements made during experiment SHEBA in Arctic and Halley 2003 experiment in Antarctica, Grachev et al. (2007) and Sanz Rodrigo and Anderson (2013) proposed different similarity functions, respectively. Through systematic mathematical analysis, Sharan and Kumar (2011) proved that similarity functions of CB05 and Grachev et al. (2007) were applicable in the whole stable stratification region. However, all of these studies are based on MOST and application of MOST in very stable condition is in doubt since it assumes that turbulence is continuous and stationary, while in very stable condition turbulence is weak, sporadic and patchy (Sharan and Kumar, 2011). Grachev et al. (2013) indicates that the applicability of local MOST in stable conditions is limited by the inequalities, when both gradient and flux Richardson numbers are below their "critical values" about 0.20-0.25. Further, MOST predicts that mean gradients of turbulence become independent of z in very stable condition, Wyngaard and Coté (1972) first referred to this limit as ‘z-less stratification’. BD equations follow this prediction, but CB05 and Grachev et al. (2007) do not. To avoid these holdbacks and self-correlation of MOST, Sorbjan (2010) and Sorbjan and Grachev (2010) discussed an alternative local scaling for the stable boundary layer (referred to as gradient-based scaling) when different universal functions plotted versus the gradient Richardson number instead of the Monin-Obukhov stability parameter.”

Minor comments:
Page 6460, lines 21-22: use identical notation for Businger-Dyer equation in both cases, B-D or BD.

Response: Revised. ‘BD’ is used.

Page 6461, lines 4-5: "Under unstable condition, the iteration normally convergeswithin 5 steps (Fairall et al., 1996)". Actually COARE 2.5 model (Fairall et al., 1996)was improved and in the next version, COARE 3.0 bulk algorithm (Fairall et al., 2003),"the stability iteration loop has been reduced from 20 to 3 by taking advantage of a bulkRichardson number parameterization for an improved first guess (Grachev and Fairall1997)." - see Fairall et al. (2003, p. 575).

Response: “By taking advantage of a bulk Richardson number parameterization for an improved first guess (Grachev and Fairall, 1997), the iteration can be reduced to 3 steps (Fairall et al, 2003).” has been added.

Page 6462, line 22. Reference Sarkar and De Ridder (2010) is missed.

Response: Reference added

Page 6468, Eq. (27). Sign minus is missed in the exponent (cf. Eqs. (6) and (27)).

Response: Sign minus added

Literature, not mentioned in the manuscript:
Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson. 2003. Bulk parameterization of air-sea fluxes: updates and verification for the COARE algorithm, J. Clim., 16(4), 571–591.
Grachev A.A., Andreas E.L, Fairall C.W., Guest P.S., Persson P.O.G. 2007. SHEBA flux-profile relationships in the stable atmospheric boundary layer. Boundary-Layer Meteorol. 124(3): 315–333. DOI 10.1007/s10546-007-9177-6
Grachev A. A., Andreas E. L, Fairall C. W., Guest P. S., Persson P. O. G. 2013. The critical Richardson number and limits of applicability of local similarity theory in the stable boundary layer. Boundary-Layer Meteorol., 147(1), 51-82, doi: 10.1007/s10546-012-9771-0
Sanz Rodrigo J, Anderson P.S. 2013. Investigation of the stable atmospheric boundary layer at Halley Antarctica. Boundary-Layer Meteorol. 148(3): 517-539. DOI:10.1007/s10546-013-9831-0
Sharan M. and Kumar P. 2011. Estimation of upper bounds for the applicability of non-linear similarity functions for non-dimensional wind and temperature profiles in the surface layer in very stable conditions. Proc. R. Soc. A. 467(2126): 473–494. DOI:10.1098/rspa.2010.0220
Sorbjan Z. 2010. Gradient-based scales and similarity laws in the stable boundary layer. Q. J. R. Meteorol. Soc. 136(650A): 1243–1254. DOI:10.1002/qj.638
Sorbjan, Z., Grachev A.A. 2010. An evaluation of the flux-gradient relationship in the stable boundary layer. Boundary-Layer Meteorol. 135(3): 385–405. DOI 10.1007/s10546-010-9482-3

Response: These references have been added.

Best wishes.

Sincerely yours,

Zhiqiu Gao together with all authors

February 7, 2014