<u>Response to the comments from Reviewer#1</u>

We thank the reviewer for his critical evaluation of the manuscript, as well as his valuable comments and suggestions. A point-wise reply to the comments of the reviewer is given below:

General Comment

Numerical weather prediction and climate models use surface flux parameterizations depending on Monin Obukhov similarity functions. Various versions of the functions exist in the literature and this paper investigates their effect on model results by using them in the WRF model. The latter is applied to a limited area in the tropics, for which surface flux data exist (the Ranchi data). The focus is on convective conditions. By comparing, e.g. model output with the observations the authors conclude finally that a certain set of functions proposed by Kader and Yaglom (1990) showing non-monotonic behaviour in unstable conditions is superior to other functions. Several sets of functions have been newly implemented by the authors in the model.

The topic is important for model applications but also for theoreticians. I find the paper interesting but the text needs better adjustment to the results shown in the figures. I expect that after such modification the study can be published finally. Before that, some paragraphs (also figures) should be improved and some points need clarification. Perhaps, several unclear issues arose due to language problems, so that I also recommend English editing before publication.

Reply: We thank the reviewer for carefully going through the manuscript and giving useful comments and suggestions, as well as encouraging remarks.

Major Revisions

Comment 1: ***My most important point refers to the differences between the results obtained with different sets of stability functions. To my mind the authors are overinterpreting the differences between the results seen in Figure 4. In my opinion the main finding is here that results obtained by CTRL and experiments 1, 2 and 3 are very similar, when the absolute value of zeta is smaller than about 1.5. Results from CTRL, exp1 and exp2 are even similar in the whole range of zeta. I think, relative to the scatter of observations, only results obtained with exp3 differ really strongly from all other results, but also only when the absolute value of zeta is larger than about 1.5. The discussion of results and conclusions should be reformulated in this direction to reflect the figures 4. The small differences explain also why most results seen in Figures 9,10,11 for different stability functions are so similar. Also here the present text suggests something else.***

Reply: We sincerely agree with the reviewer's concern. It is true that experiments 1, 2, and 3 (Exp1-3) and the CTRL simulation using the default version of the surface layer scheme in the WRF model seem to be identical when ζ lies between 0 and −1.5 (approx.), as stated in section 4.1. Moreover, we also agree with the fact that at higher instabilities, only Exp3 shows substantial differences, while Exp1, 2, and CTRL simulations are found to be nearly identical.

As per the reviewer's suggestions, we modified the text in the revised version of the manuscript for better clarity and presentation of the results for general readers. The modified text is presented here for reviewers' reference:

Lines 233-237…It is observed that the simulated values of ζ at smaller values of Ri_B (i.e., in DNS to DCS) from different forms of similarity functions are found to be identical to the F96 forms of functions (Figure 4a1-3). Moreover, results from the BD71, CL73, and F96 functions are even similar at higher instabilities (i.e., the whole range of ζ values), while substantial differences have been observed in the simulated values of ζ for a given Ri_B from Exp 3 (Figure 4a1-3).

Moreover, we also agree with the fact that the results obtained from Exp3 differ really strongly from all other results, but only when the absolute value of zeta is larger than about 1.5. The related text is modified accordingly in the revised version of the manuscript and stated here for reviewers' reference:

Lines 277-282…The values of simulated variables are found to be almost identical in DNS to DCS sublayers for all the experiments. Moreover, in FCS, the results obtained from Exp1, 2 and CTRL simulation are found to be nearly similar; however, relatively strong differences have been observed in results from Exp 3 (Figures 5a, b, and c). Simulated ζ for a given Ri_B in Exp2 and CTRL simulation are similar and found to be relatively smaller in magnitude than Exp1 and Exp3 in FCS. However, the absolute values of ζ in Exp3 (KY90 functions) are relatively higher in FCS than in all other experiments.

Moreover, the comparison of model simulated variables, namely (a) u_*^2 ($m^2 s^{-2}$) (representative of momentum flux), (b) SHF ($W m^{-2}$) (sensible heat flux), (c) U_{10} ($m s^{-1}$) (10-m wind speed), and (d) T_{2m} (K) (2-m temperature), with the observed data obtained from the flux tower at Ranchi (23.412N, 85.440E; India) presented in section 4.2.1 clearly highlights that only Exp3 shows strong differences in the simulated values than all other experiments as well as CTRL simulation.

Figures 9, 10, and 11, which are used to evaluate the mean spatial distribution of simulated variables against ERA5-Land reanalysis data during daytime. While we sincerely agree that the differences between the results presented in Figures 9, 10, and 11 are small, we want to emphasize that some variables (hatched regions of Figures 9, 10, and 11) show significant differences at the 95% confidence interval. The corresponding text has been modified accordingly in the revised version of the manuscript. The modified text is presented here for reviewers' reference:

Lines 354-357…It is observed that the absolute value of ζ simulated in Exp3 (KY90 functions) is relatively smaller than CTRL simulation (Figure 9b3) across the whole domain, which is consistent with Figure 5a and offline simulations presented in Figure 4(a1-3). This could be because the magnitude of the KY90 functions (φ_m and φ_h) is relatively smaller than the functions employed in the default scheme (CTRL simulation).

Lines 359-366…Model simulated C_D is found to be relatively smaller in Exp3 than CTRL simulation (Figure 9d3), while Exp1 and Exp2 provide comparable values of C_D to CTRL simulation (Figure 9d1-2). In the case of C_H, the simulated values from different experiments are observed to be comparable to the CTRL simulation over the whole study domain (Figure 9f1-3). Note that simulated C_H is found to be comparable in all the experiments, while slight differences have been observed in C_D in Exp 3 compared to all other experiments, which may be related to the fact that only φ_m functions are involved in the computation of C_D (Eqn. 1), and the differences between φ_m corresponding to Exp3 are relatively more than φ_h, so are the differences in C_D. The hatched regions in Figure 9 show that the differences between simulated variables from different experiments with respect to CTRL simulation are statistically significant at the 95% confidence level.

Lines 367-372…The slight differences in C_D in Exp3 were further reflected in the simulated u_*^2 m^2 s^{-2} (a measure of momentum flux) (Figure 10b3). A slight reduction has been observed in simulated u_*^2 in Exp3 compared to the CTRL simulation over some parts of the domain (Figure 10b3), while in Exp1 and Exp2 values are comparable with the CTRL simulation (Figure 10b1-2). In case of SHF and LHF, the mean spatial distribution from all the experiments is found to be consistent with the ERA5-Land reanalysis data, and the magnitude of differences between model simulation and ERA5-Land data is comparable for all the experiments (Table S1; supplementary material).

Comment 2: I think that the differences between the offline simulation and what is called here 'real-case' simulations using four sets of stability correction functions (default scheme, BD71, CL73, KY90) in WRF should be made clearer. E.g. I recommend to avoid the expression 'real' in this connection and to replace the heading 'Real Case Simulations' by something like 'Results of WRF using different sets of integrated stability correction functions'.

Reply: As suggested by the reviewer, we have replaced the heading 'Real-Case Simulations' by 'Results of WRF using different sets of integrated similarity functions' in the revised version of the manuscript as suggested by the reviewer.

Comment 3: The offline-simulations would become clearer, if they were not called 'experiment'. What we see in the figure, are the functional dependences of several

parameters from stability and surface roughness. The wording 'experiment' is more appropriate for the different model applications.

Reply: We agree with the reviewer's suggestion about the offline simulations. The text related to this has been modified in the revised version of the manuscript and presented here for reviewers' reference:

Lines 222-259…To analyze the functional dependence of ζ, C_D, and C_H on the utilized forms of similarity functions, offline simulations independent of the WRF model have been conducted utilizing newly installed functions (BD71, CL73, and KY90) together with F96 functions existing in the default version of the surface layer scheme of the WRF model for three different roughness lengths for momentum (z_0), which are representative of smooth ($z_0 = 0.01$ m), transition ($z_0 = 0.1$ m), and rough ($z_0 = 1.0$ m) surfaces. Different values of z_0 are chosen to analyze the role of z_0 in the simulation of ζ, C_D, and C_H from different similarity functions. The results for ζ (a1, a2, and a3) with Ri_B, C_D (b1, b2, and b3), and C_H (c1, c2, and c3) with ζ across various surface types and sublayers have been analyzed (Figure 4). The different sublayers associated with convective stratification include dynamic (DNS), dynamic-dynamic convective transition (DNS-DCS), dynamic convective (DCS), dynamic convective-free convective transition (DCS-FCS), and free convective (FCS) (Srivastava and Sharan, 2021). Note that the sublayers DNS ($-0.04 \le \zeta \le 0$) and DNS-DCS transition ($-0.12 \le \zeta < -0.04$) are corresponding to weakly to moderately unstable conditions, while sublayers DCS ($-1.20 \le \zeta < -0.12$), DCS-FCS ($-2.0 \le \zeta < -1.20$), and FCS ($\zeta < -2.0$) belong to moderately to strongly convective conditions (Srivastava and Sharan, 2015). It is observed that the simulated values of ζ at smaller values of Ri_B (i.e., in DNS to DCS) from different forms of similarity functions are found to be identical to the F96 functional forms (Figure 4a1-3). Moreover, results from BD71, CL73 and F96 functions are even similar at higher instabilities (i.e. whole range of ζ values) while substantial differences have been observed in the simulated values of ζ for a given Ri_B from Exp 3 (Figure 4a1-3). Notably, BD71, CL73, and F96 functional forms predict relatively smaller absolute values of ζ for a given value of Ri_B. However, KY90 functions are found to produce a relatively larger magnitude of ζ for a given value of Ri_B. This behaviour is observed to be consistent for all the values of ratio z/z_0 (Figures 4a1-3) representative of smooth, transitional, and rough surfaces. A relatively larger magnitude of ζ for a given value of Ri_B and the smaller values of ψ_m and ψ_h (Figure 2) in KY90 functional forms implies that the momentum and heat fluxes predicted using KY90 functions will be smaller than those anticipated in BD71, CL73, and F96 functional forms.

Figure 4b1-3 shows the variation of C_D with ζ estimated using BD71, CL73, KY90, and F96 functional forms over different surfaces. Notice that the C_D values calculated from the BD71, CL73, and F96 forms of functions are substantially higher and continue to rise as instability progresses from DCS to FCS. On the other hand, KY90 functional forms simulate significantly smaller values of C_D as compared to the other three functional forms of similarity functions. It is important to highlight that C_D estimated using KY90 functions shows a non-monotonic behaviour, which is consistent with the observed behaviour of C_D over the Indian region reported in the literature (Srivastava and Sharan, 2019; 2021). Note that this non-monotonic behaviour is consistent for all three cases of different roughness lengths (Figure 4b1-3).

On the other hand, across all three surfaces, it is observed that the values of C_H estimated from all four functional forms increase with increasing instability (Figure 4c1-3). While the rate of increase of C_H in KY90 functions is noticeably slower. Moreover, BD71, CL73, and F96 functions predict almost similar values over all three types of surfaces. Noticeably, C_H estimated using KY90 functions also exhibits non-monotonic behaviour with ζ over rough surfaces, which contradicts the predictions of the other three functional forms. In addition, it is important to note that C_D and C_H predicted by KY90 functional forms are found to be bound by twice their near-neutral values, while the other functional forms predict continuously increasing values of C_D and C_H on increasing instability.

Hence, it is evident that the BD71, CL73, and F96 functional forms predict values of ζ, C_D, and C_H that are almost the same over all three different surface types. However, using KY90 functions compared to other commonly used φ_m and φ_h, one can expect a significant reduction in the estimated values of transfer coefficients in moderately to strongly unstable stratification.

Moreover, we wish to highlight that the figure corresponding to offline simulation has also been modified accordingly and presented here for reviewers' reference:

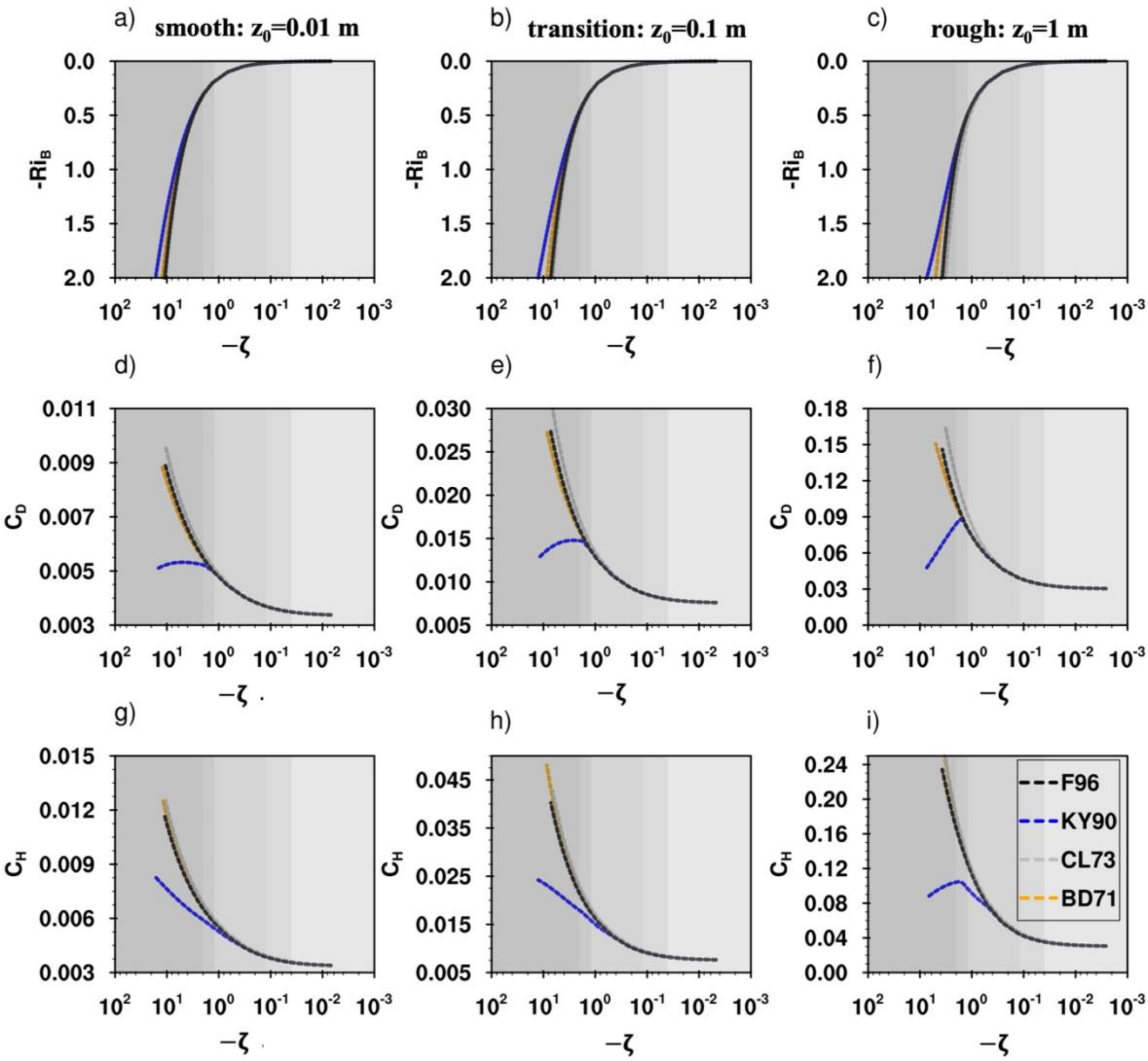

Figure 4: Variation of ζ with Ri_B (upper panel), C_D (middle panel) and C_H (lower panel) with ζ calculated from bulk flux algorithm (offline simulation) for different functional forms of ψ_m and ψ_h corresponding to BD71, CL73, KY90, and F96 forms for smooth (z_0 = 0.01 m; 1st column), transition (z_0 = 0.1 m; 2nd column), and rough (z_0 = 1 m; 3rd column) surfaces. The background colour corresponds to different sublayers in convective conditions (Kader and Yaglom 1990) from dynamic sublayer ($0 > \zeta > -0.04$; light grey) to free convective sublayer ($\zeta < -2$; dark grey).

Comment 4: I wonder also why the observations (Figure 5a) are not shown already in Figure 4. If the different surface roughnesses are the reason, this must be explained. Also, the reader should know why in Figure 5 Ch shows variability for a given zeta, but no scatter is seen in Cd. I guess, the reason is the parametrization of the ratio of momentum roughness and scalar roughness, but this must be said. Which are the values for the observations and which parameterization is used for this ratio in WRF?

Reply: We have not shown observational data for C_D in Figure 4 since Figure 4 is used to describe the dependence of estimated ζ, C_D, and C_H on different functional forms of similarity functions in a theoretical framework, and we have estimated these variables for three different values of momentum roughness length (z_0), which are representative of smooth ($z_0 = 0.01$ m), transition ($z_0 = 0.1$ m), and rough ($z_0 = 1.0$ m) surfaces. Since the observational data site has a different roughness length for momentum, we have not included the observed C_D in Figure 4.

To the best of our knowledge, the WRF model utilizes constant values for roughness length, and the momentum and scalar roughness lengths are assumed to be similar over the land surface. However, the relatively large scatter in the values of C_H simulated from the WRF model may be linked with the fluctuations in the temperature difference term ($\theta_a - \theta_g$).

As per the reviewer's suggestion, text has been added in the revised version of the manuscript and presented here for the reviewers' reference:

Lines 260-264…Note that Figure 4 is used to describe the dependence of estimated ζ, C_D, and C_H on different functional forms of similarity functions in a theoretical framework, and we have estimated these variables for three different values of momentum roughness length (z_0), which are representative of smooth ($z_0 = 0.01$ m), transition ($z_0 = 0.1$ m), and rough ($z_0 = 1.0$ m) surfaces. Since the observational data site has a different roughness length for momentum, we have not included the observed C_D in Figure 4.

Lines 310-314…We wish to point out that a relatively larger scatter has been observed in the values of C_H than C_D. To the best of our knowledge, the WRF model utilizes constant values for roughness length, and the momentum and scalar roughness lengths are assumed to be similar over the land surface. However, the relatively large scatter in the values of C_H simulated from the WRF model may be linked with the fluctuations in the temperature difference term ($\theta_a - \theta_g$).

Comment 5: Considering Figure 5a) it seems that the stability range, for which KY results diverge from other results, does not occur in nature, but at least not in the Ranchi data. This should be stressed. Are there other observations, which show a better agreement with the used functions? This should at least be discussed.

Reply: Indeed, the Ranchi data does not display the stability range where the KY90 functions' results diverge from other similarity functions. Due to the limited availability of observational datasets, the validity and practical applicability of these functional forms to reduce the uncertainties in surface flux formulations are limited, specifically over Indian land. In this study, we wish to compare the performance of the four different functional forms of similarity functions under convective conditions in the surface layer scheme of the WRF model with respect to the Ranchi dataset. It is observed that the KY90 functional forms are the only ones among all the considered functions that can predict C_D consistent with its observed non-monotonic behaviour over Indian land. At the same time, the study also highlights that the C_D predicted from the original forms of KY90 functions shows large disagreement with the observed data, as the predicted C_D starts decreasing at ζ lying in FCS, which is different from that observed, i.e., ζ lying in DCS. In light of this, the study further pointed out the need to tune the original form of KY90 functions.

Note that a study by Srivastava and Sharan (2021) attempted to tune the original forms of KY90 functions by enforcing the matching of the point at which both observed and model predicted C_D attain their maximum value. However, more studies in terms of predicting the observed variation of the non-dimensional vertical gradients of mean wind speed and temperature with ζ are essential to further tune the original KY90 functions for the Indian region using observed data from various locations and seasons.

We wish to highlight that the KY90 functional forms show relatively better agreement with the Ranchi dataset for u_*^2 (a representative of momentum flux) and U_{10} (10-m wind speed) and found comparable for other considered variables when employed in the surface layer scheme of the WRF model.

Further, we would like to point out that currently no observational datasets are available that show better agreement with the KY90 functions over Indian land. However, it is desirable to validate these functional forms over Indian land with respect to such observational datasets if they are available in the future.

As suggested by the reviewer, we have added text to the revised version of the manuscript to discuss this issue and presented it here for the reviewer's reference:

Lines 292-304…However, it is found that the C_D predicted from the original forms of class 4 functions (Exp3) shows large disagreement with its observed behaviour, as the predicted C_D starts decreasing at ζ lying in FCS, which is different from that observed, i.e., ζ lying in DCS. In light of this, the study further pointed out the need to tune the original form of KY90 functions and the need for more studies to further evaluate the performance of the original forms of KY90 functions in the WRF model using different available observational datasets from different Indian land sites and seasons.

Note that Srivastava and Sharan (2021) tuned the original forms of class 4 functions by enforcing the matching of the point at which both observed and model predicted C_D attain their maximum value. However, more studies in terms of predicting the observed variation of the non-dimensional vertical gradients of mean wind speed and temperature with ζ are essential to further tune the original KY90 functions for the Indian region using observed data from various locations under different seasons.

Further, we would like to point out that currently no observational datasets are available that show a better agreement with the KY90 functions over Indian land. However, it is desirable to validate these functional forms over Indian land with respect to such observational datasets if they are available in the future.

Other recommendations:

Comment 1: Line 136: all this would be more convincing if data would be added in Figures S1a and b, Also, the reader would like to know if KD had perhaps physical arguments for proposing non-monotonous functions.

Reply: Figures S1a and b show the variation of the newly installed (BD71, CL73, and KY90) and default φ_m and φ_h with respect to $-\zeta$ under convective conditions. Thus, we have just plotted different φ_m and φ_h with ζ in the range $(-100, 0)$. This figure suggests that φ_m based on KY90 functional forms exhibits a contrasting behaviour; however, all other functional forms are more or less similar.

Note that the KY90 functional forms are based on the three layer structure of the convective regime proposed by Kader and Yaglom (1990). The dynamic sublayer corresponds to near-neutral conditions in which $\varphi_m = 1$ and $\varphi_h = Pr_t$. Further, in the dynamic convective sublayer, mechanical energy is in the x direction, while buoyancy-induced energy is in the z direction. Thus, in this sublayer, the functional forms for similarity functions, as determined by dimensional analysis, are

$$\varphi_m(\zeta) = A_u(-\zeta)^{-\frac{1}{3}} \tag{R1}$$

$$\varphi_h(\zeta) = A_T(-\zeta)^{-\frac{1}{3}} \tag{R2}$$

in which A_u and A_T are constants.

Moreover, in the free-convective sublayer, buoyancy dominates the mechanical production of energy, and the pressure redistribution term feeds the buoyant energy in the vertical direction into the horizontal direction (Kader and Yaglom, 1990). Thus, in this case, the dimensional analysis suggests

$$\varphi_m(\zeta) = B_u(-\zeta)^{\frac{1}{3}} \tag{R3}$$

$$\varphi_h(\zeta) = B_T(-\zeta)^{-\frac{1}{3}} \tag{R4}$$

in which B_u and B_T are constants.

Thus, as stated above, in the three layer model, φ_m follows a $-1/3$ power law in the dynamic convective sublayer; however, $+1/3$ power in the free convective sublayer is based on the dimensional analysis, which shows a non-monotonic behaviour of φ_m with $-\zeta$ under convective conditions. This contradicts the behaviour of φ_m predicted by the classical free convection limit.

Comment 2: Line 167: 'without feedback to the atmosphere'...this formulation might be misleading because this offline simulation is completely independent from WRF. So I would recommend writing something like (starting from line 164): The performance of the default and newly installed similarity functions is investigated in two steps. The first one is independent on the WRF model. Namely, we apply equation A7 to iteratively determine Cd and Ch as a function of zeta by prescribing the bulk Richardson number and surface roughness parameters z_m and z_h...... We call this in the following offline simulation.

Reply: As per the reviewer's suggestions, the text has been modified in the revised version of the manuscript and stated here for the reviewers' reference:

Lines 190-196…To analyze the impacts of newly installed similarity functions together with the existing functional forms in the surface layer scheme of WRFv4.2.2, the performance of the default and newly installed similarity functions is investigated in two steps. The first one is independent of the WRF model. Namely, we apply Eqn. (B7) (Appendix B) to iteratively determine C_D and C_H as a function of ζ by prescribing the bulk Richardson number (Ri_B) and surface roughness parameters for momentum (z_0) and heat (z_h). Note that the values of z_0 and z_h are assumed to be same. The value of ζ is estimated by calculating the root of least magnitude of Eqn. (B7) for a given value of Ri_B. Once ζ is calculated then utilizing it in Eqns. (B8) and (B9), the values of C_D and C_H can be estimated. We call this in the following offline simulation.

Comment 3: And later in the text, where you start describing the model application. The second step is to apply all parameterizations of the similarity functions in the model WRF whose output is compared then with observations.

Reply: The text has been modified as per the reviewer's suggestion and is presented here for reviewers' reference:

Lines 200-202…The second step is to apply all the parameterizations of the similarity functions in the WRF version 4.2.2 model over an Indian land site whose output is compared with the observations during the pre-monsoon (March-April-May; MAM) season of the year 2009.

Comment 4: Line 203: I do not really see large differences. There is only the function KY90, which produces really large differences to all others. If you think differences between the other functions are also large, this must be better explained. In the present figures I cannot see any relevant difference between results from EXP1, EXP2 and CTRL. There might be a

tendency for differences increasing with surface roughness in case of -zeta larger than 1 ? When this is the case, another figure showing this in a zoomed version might be helpful.

Reply: Yes, only the KY90 functional forms show large differences, and all the other functional forms are more or less similar. We have modified the text accordingly in the revised version of the manuscript and presented it here for reviewers' reference:

Lines 233-237… It is observed that the simulated values of ζ at smaller values of Ri_B (i.e., in DNS to DCS) from different forms of similarity functions are found to be identical to the F96 functional forms (Figure 4a1-3). Moreover, results from the BD71, CL73, and F96 functions are even similar at higher instabilities (i.e., the whole range of ζ values), while substantial differences have been observed in the simulated values of ζ for a given Ri_B from Exp 3 (Figure 4a1-3).

Comment 5: Line 210: I do not see that they are really 'substantially' higher (?)

Reply: The related text has been modified in the revised version of the manuscript and is presented here for reviewers' reference:

Line 244-245… Notice that the C_D values calculated from the BD71, CL73, and F96 forms of functions are relatively higher than the C_D produced by the KY90 functional forms and continue to rise as instability progresses from DCS to FCS.

Comment 6: Line 223-225: This last paragraph is the main finding to which I can agree. But this should come earlier, so that this whole subsection could be shortened. But I have another point. Namely, Figure 5 shows that for much stronger instability, differences between all functions become more pronounced. So, why is that not shown already in Section 4.1?

Reply: As stated in the earlier replies, only the KY90 functional forms show large differences in the simulated variables; however, all other functional forms are found to be approximately similar. Figure 5 also suggests that the simulated ζ, C_D, and C_H from KY90 functions show large differences for much stronger instabilities; however, all the functions are more or less similar in producing ζ, C_D, and C_H.

Note that the text has been modified accordingly in the revised version of the manuscript.

Comment 7: Line 237: it should not be only consistent, but results should be identical if the same roughness parameters are used. Please note that the Rib-zeta curves depend only on height and roughness parameters but not on any other external parameter.

Reply: We agree with the fact that the Ri_B-ζ curves depend only on the height and roughness parameters. We have modified related text in the revised version of the manuscript.

Comment 8: Line 249: This is not an appropriate formulation. There is a very large disagreement, one should not simply write only that there is no perfect match. Note that the functional forms are completely different.

Reply: The text has been modified and presented here for reviewers' reference:

Lines 292-294…However, it is found that the C_D predicted from the original forms of class 4 functions (Exp3) shows large disagreement with its observed behaviour, as the predicted C_D starts decreasing at ζ lying in FCS, which is different from that observed, i.e., ζ lying in DCS.

Comment 9: Figures must be improved. E.g., in Figure 7, one cannot read the numbers (especially number 3 is unreadable). Please increase also the font size of headings in all figures showing horizontal cross-sections of model results. These headings are almost unreadable without zooming in, for which, however, the resolution is not good enough.

Reply: All the figures have been modified and presented here for reviewers' reference:

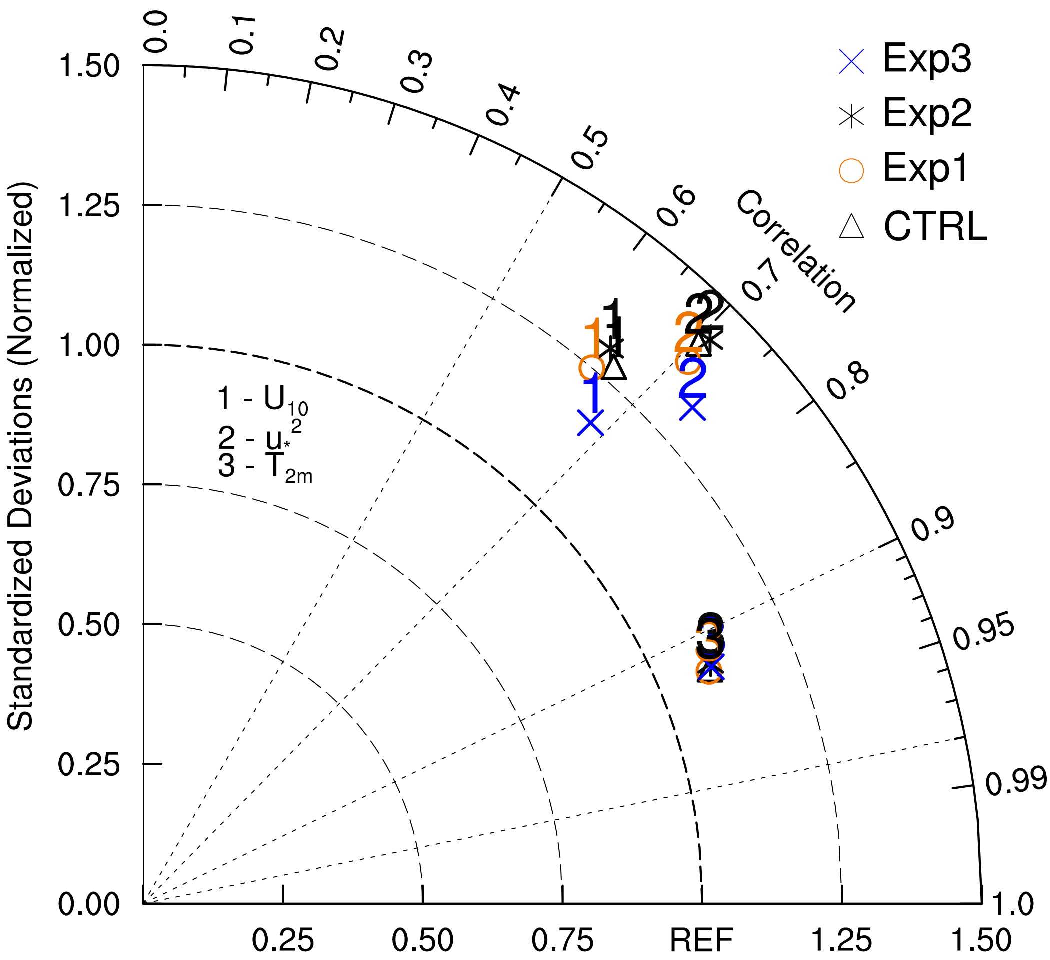

Figure 7: Taylor diagram showing the correlation coefficient, normalized standard deviations for U_{10}, u_*^2, and T_{2m} from different experiments together with CTRL simulation with respect to observations derived from flux tower installed at Ranchi (23.412^{O}N, 85.440^{O}E), India.

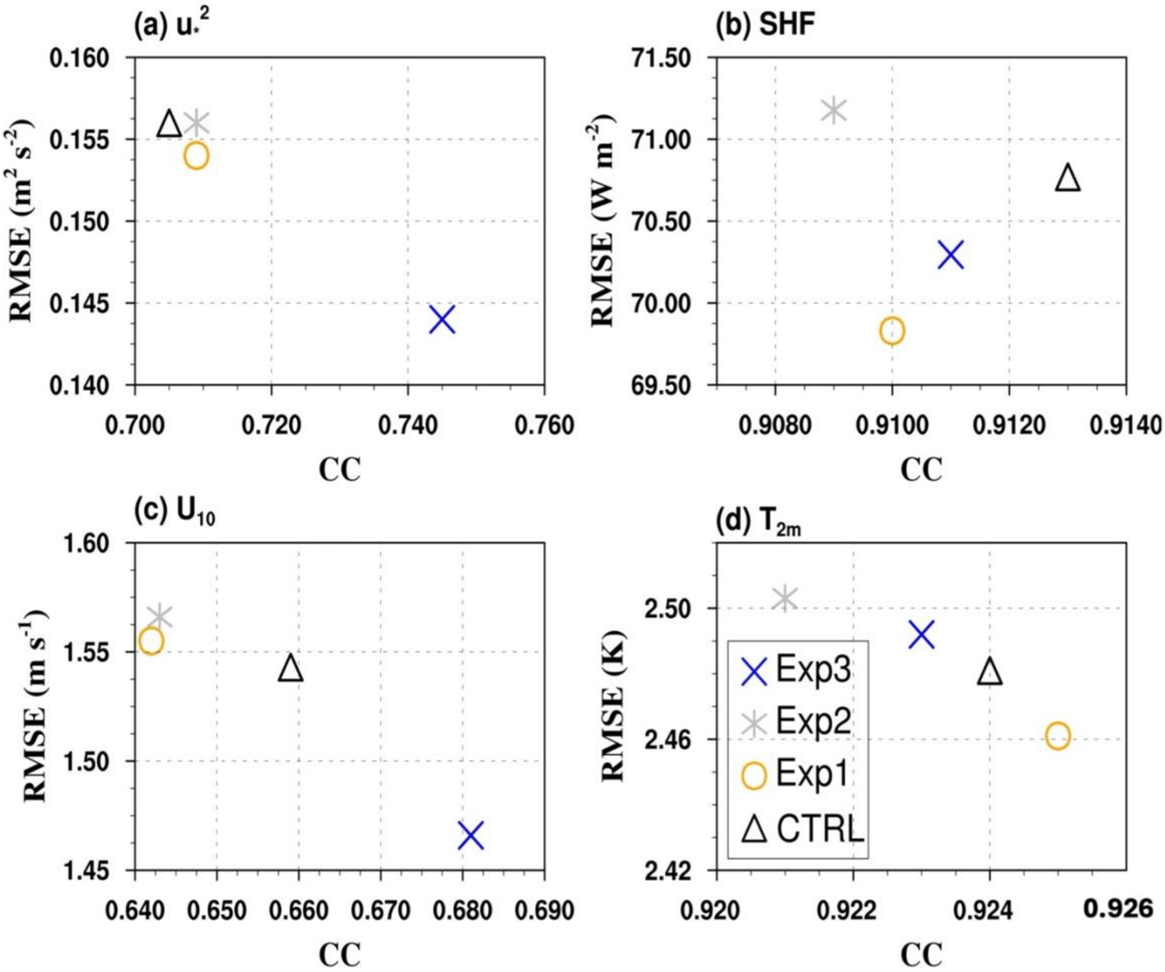

Figure 8: Scatter plot between correlation coefficient (CC) and root mean square error (RMSE) for (a) u_*^2, (b) SHF, (c) U10, and (d) T2m simulated by various experiments (Exp1-3) together with CTRL simulation for pre-monsoon season (MAM; 2009) at the location of the flux tower (23.412^{o}N, 85.440^{o}E).

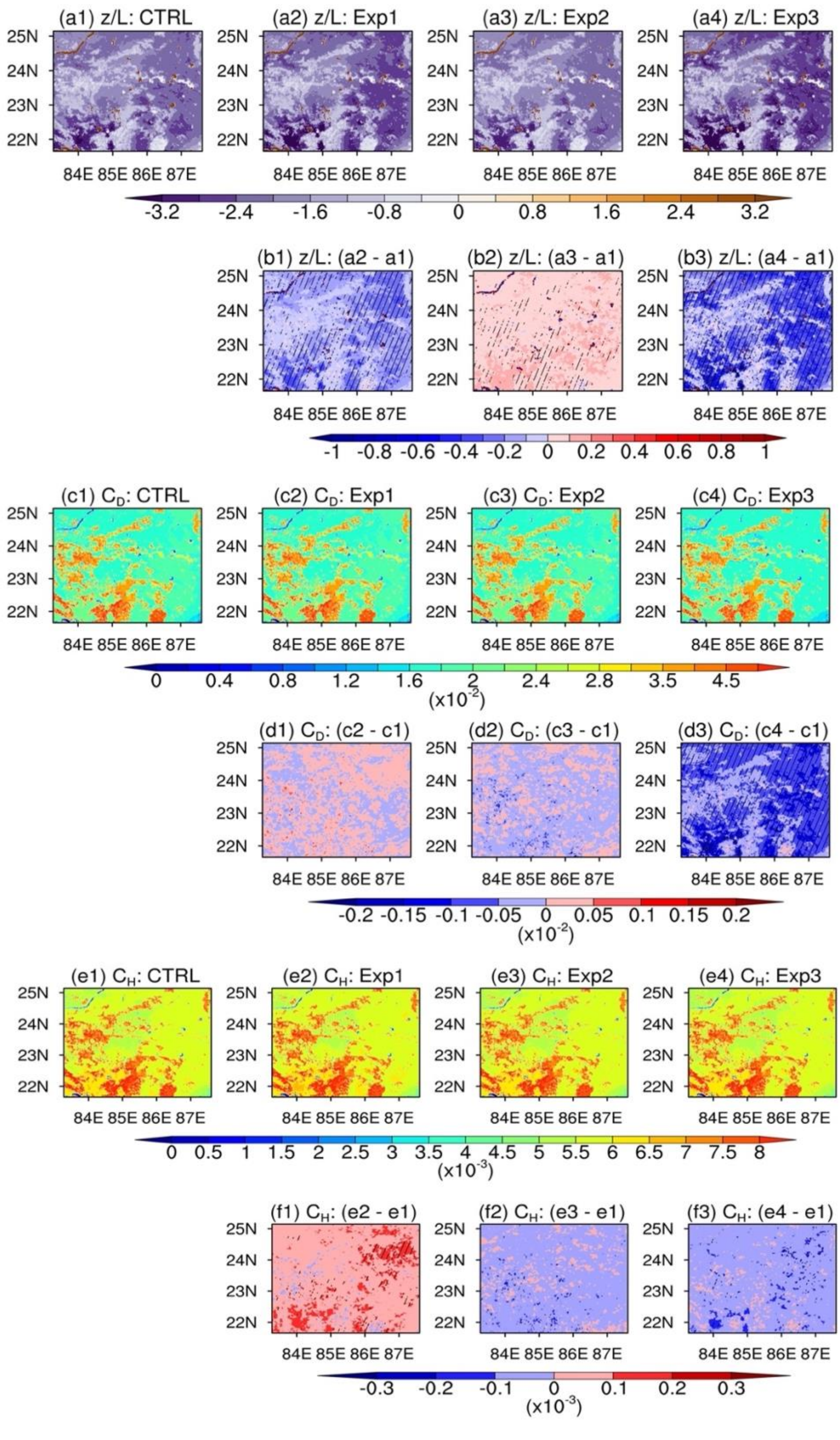

Figure 9: Mean spatial distribution of model simulated **ζ** (1st row), $\mathbf{C_D}$ (3rd row) and $\mathbf{C_H}$ (5th row) from different experiments and their differences with respect to CTRL simulation averaged during daytime for whole simulation period. Hatched regions show significant differences at 95% confidence level in experiments with respect to CTRL simulation.

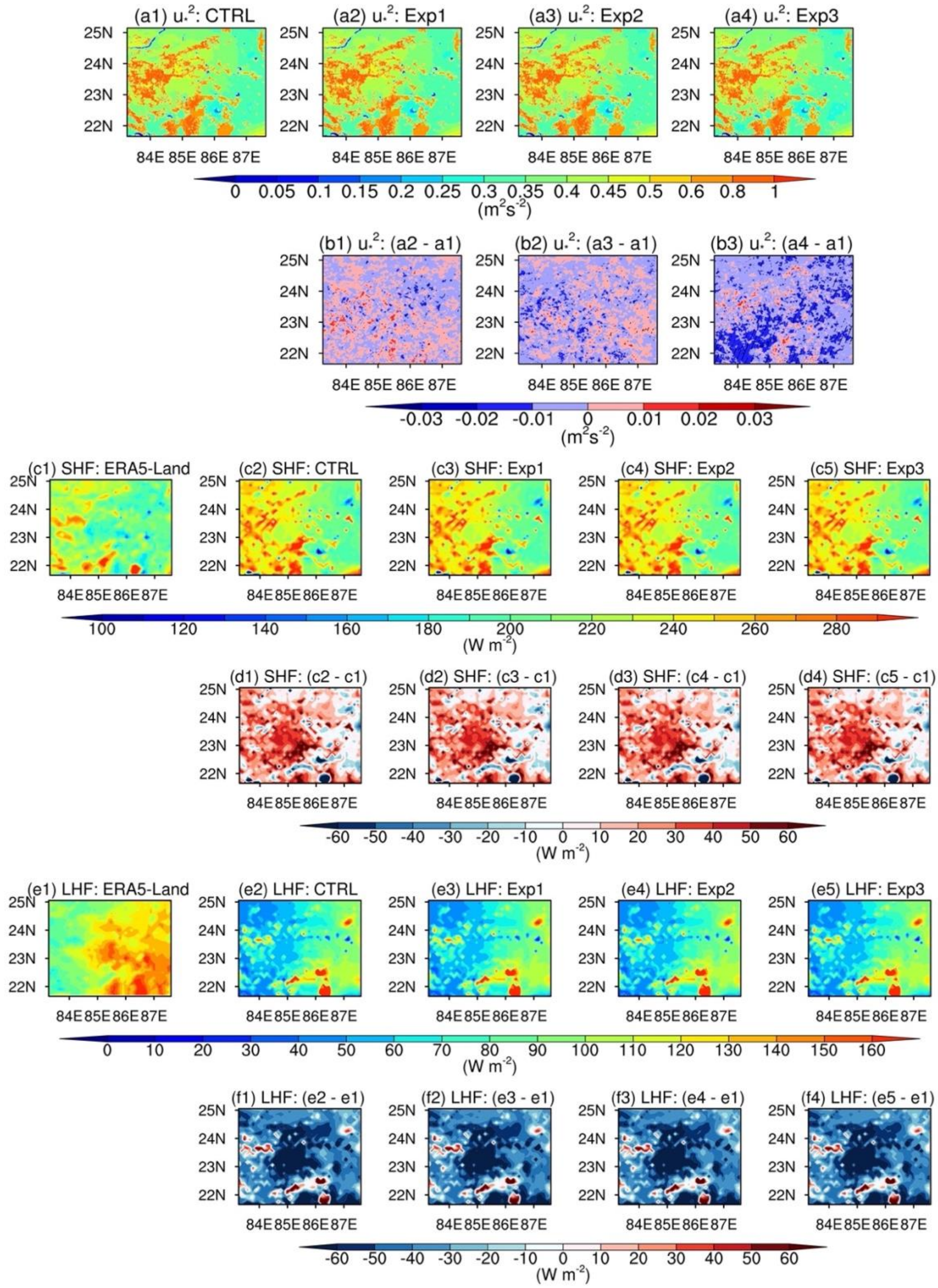

Figure 10: Mean spatial distribution of simulated u_*^2 (1st row) from different experiments and their differences (2nd row) with respect to CTRL simulation. SHF and LHF from ERA5-Land reanalysis and simulated using various experiments and their differences with respect to ERA5-Land data averaged during daytime for the whole simulation period are shown. Hatched regions show significant differences at 95% confidence level in experiments with respect to CTRL simulation.

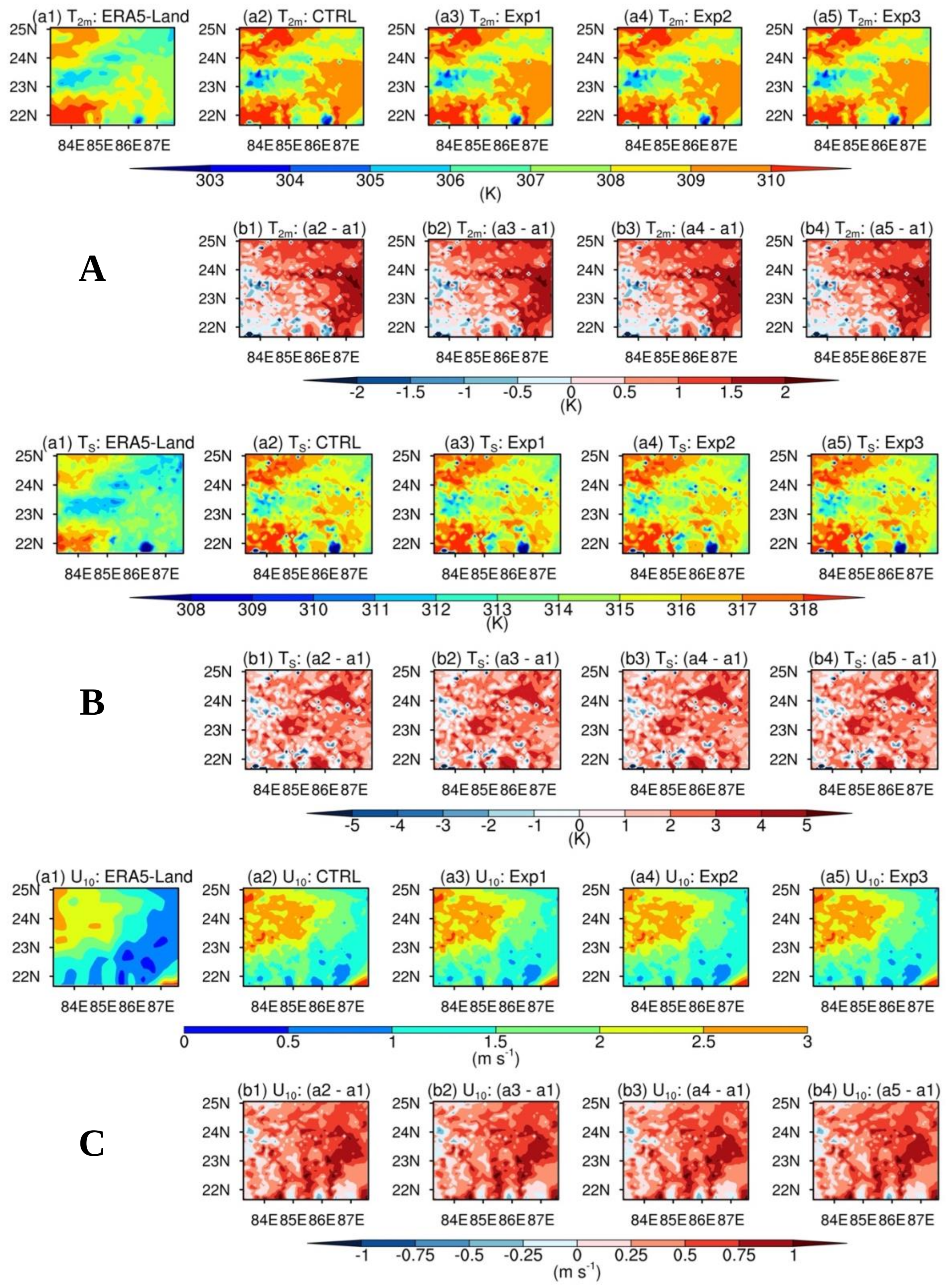

Figure 11: In upper panel (A), mean spatial distribution of T_{2m} from ERA5-Land reanalysis (a1) and simulated using different experiments (a2-a5) and their differences with respect to ERA5-Land reanalysis (b1-b4) averaged during daytime for the whole simulation period. Middle (Lower) panel is same as the upper panel but for T_S (U_{10}).

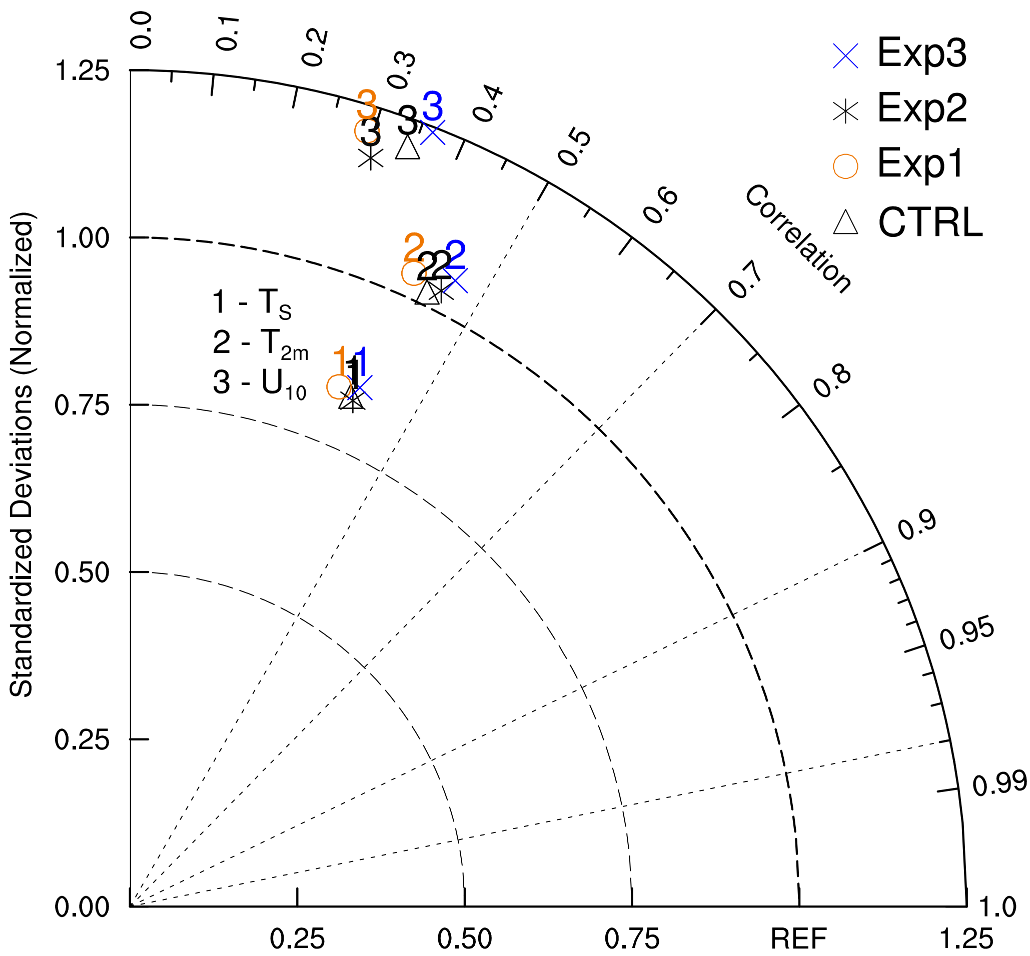

Figure 12: Taylor diagram showing the correlation coefficient, normalized standard deviations for T_S (K), T_{2m} (K), and U_{10} (m s^{-1}) from different experiments together with CTRL simulation with respect to ERA5-Land reanalysis dataset averaged during strong convective conditions (hours during daytime in which $\boldsymbol{\zeta}$ is smaller than $\mathbf{-10}$) for whole simulation period.

Minor Revisions

Most of these minor revisions refer to language problems, e,g, at many places the English article 'the' is not used correctly or it needs to be added. I give many examples.

Comment 1: Line 12: is 'all' really correct, aren't there more such functions?

Reply: It is modified in the revised version of the manuscript. The revised text is presented here for reviewers' reference:

Line 12…The surface layer module in WRFv4.2.2 is modified in such a way that it contains the commonly used similarity functions for momentum (φ_m) and heat (φ_h) under convective conditions instead of the existing single functional form.

Comment 2: Line 12: replace 'used phi_m' by 'used similarity functions phi_m' . (The symbols need to be explained at their first occurrence.)

Reply: The needful is done.

Comment 3: **Line 28: replace near neutral' by 'near-neutral'. This occurs at many places in the text, I will not repeat it. So please check it.**

Reply: The word "near neutral" has been replaced with "near-neutral" throughout the modified text.

Comment 4: Line 20: do you mean here in the WRF model or in other numerical models as well? The formulation leaves this open. So, what do you mean with 'the ... model? Perhaps a language problem.....

Reply: Yes, it is just for the WRF model, and the text is modified accordingly and is presented here for reviewers' reference:

Lines 19-20…The study suggests that the updated surface layer scheme performs well in simulating the surface transfer coefficients and could be potentially utilized for parameterization of surface fluxes in the WRF model.

Comment 5: Line 52: when you write WRF model, then it should always be 'the model'. Only when you write just WRF (without the word model) then 'the' can be omitted. This arises at many places in the whole text.

Reply: The text has been modified accordingly.

Comment 6: Line 65: Replace perhaps 'the available' by all available' ?

Reply: The needful is done.

Comment 7: Line 68: no comma after which

Reply: The needful is done by removing the comma.

Comment 8: Lines 82-84: The structure is a little puzzling here and I recommend therefore to replace the sentence by something like: Their determination based on MOST using integrated forms of the similarity functions is explained in Appendix A. In the following, the default similarity functions used in WRF are explained and further functions are introduced in Section 2.2.

Reply: The needful is done by modifying the sentence accordingly.

Comment 9: Line 100: Already here the abbreviation F96 must be introduced, which is used later (?)

Reply: The needful is done by introducing the abbreviation F96.

Comment 10: Line 102: At this point, the formulation is somehow unclear and I was not yet sure here if these functions are already implemented in WRF or if this implementation is the topic of the paper. It should become clear already here.

Reply: The needful is done, and the modified text is presented here for reviewers' reference:

Lines 118-121…In this section, we briefly describe the implementation of different similarity functions under unstable stratification in the surface layer parameterization of WRFv4.2.2. Note that the functional forms suggested by Carl et al. (1973) and the three sub-layer model suggested by Kader and Yaglom (1990) for convective conditions have not been installed and tested in the revised MM5 surface layer in the WRF modeling framework.

Comment 11: Line 106: replace 'these functions' by 'They'

Reply: The needful is done.

Comment 12: Line 112: Better write: equations (B3) and (B4) (Appendix B)

Reply: As per another reviewer's suggestion, appendix B is now interchanged with appendix A, and equations (B3) and (B4) are now referred to as equations (A3) and (A4). The text has been modified accordingly in the revised version of the manuscript.

Comment 13: Line 113: Have not been analyzed by you or by others as well?

Reply: To the best of our knowledge, the functional forms suggested by Carl et al. (1973) have not yet been installed and evaluated in the revised MM5 surface layer scheme of the WRF model.

Comment 14: Line 114: are given by Equation (6)

Reply: The needful is done.

Comment 15: Line 127: Mentioning this program parameter is a very specific information for those who are using this model. I suggest describing this more generally or add this very technical description in an appendix.

Reply: The text mentioning this program parameter is already included in the manuscript and is presented here for reviewers' reference:

Lines 143-148…Here, we have introduced a new surface layer module where different options for φ_m and φ_h can be controlled using an appropriate value of the namelist parameter (psimhu_opt). The parameter psimhu_opt is added under the physics section of the namelist file. The variable psimhu_opt can have values 0, 1, 2, and 3 for different options for functions F96 (default), BD71, CL73, and KY90, respectively. Moreover, a brief structure and different choices for psimhu_opt based on newly installed and default functional forms of φ_m and φ_h in the default and modified revised MM5 scheme are shown in Figure 1.

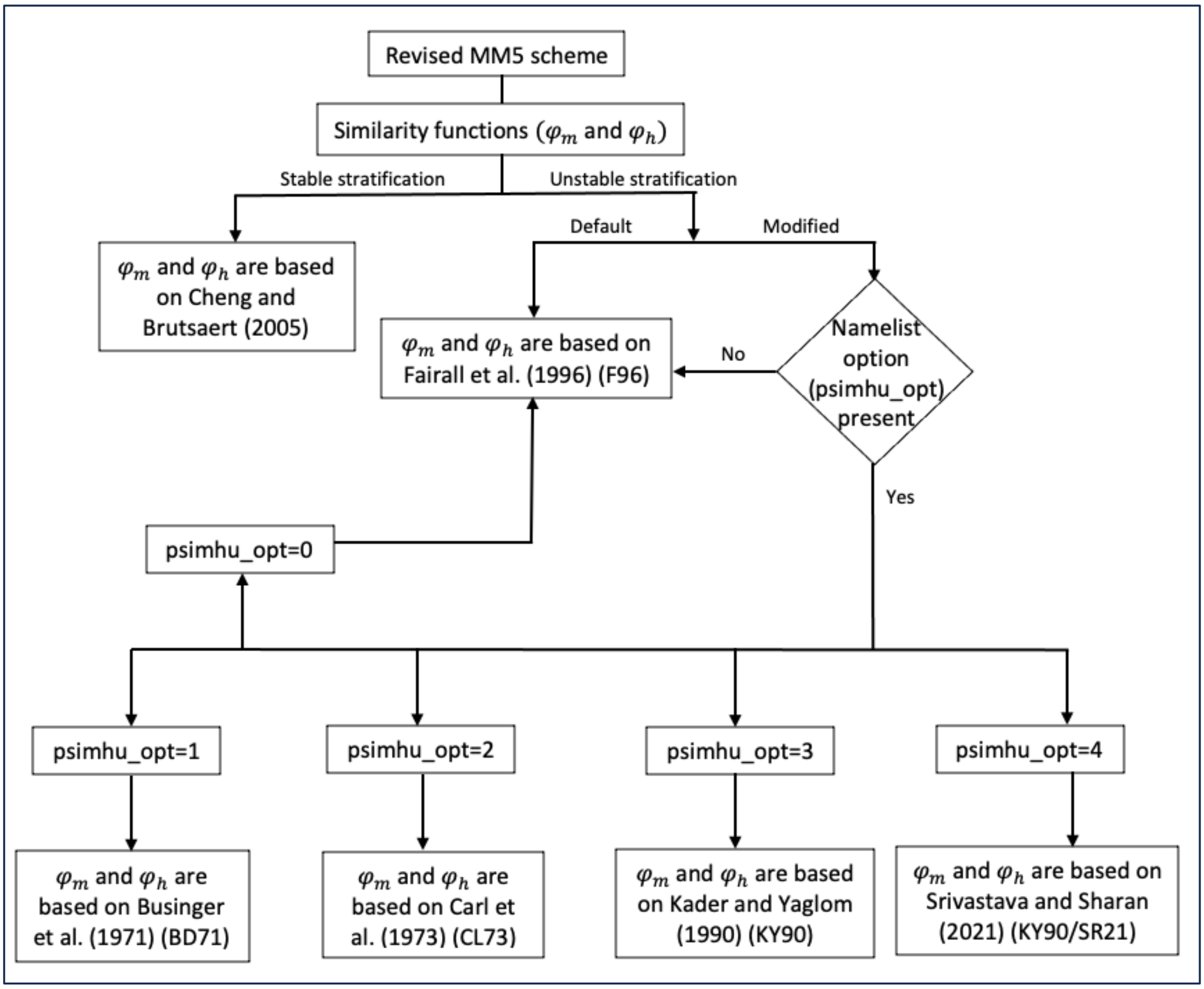

Figure 1: Flowchart to provide a brief description of different options for similarity functions in the modified surface layer scheme that can be controlled by namelist variable psimhu_opt.

Comment 16: Line 144: replace 'strong' by 'strongly'

Reply: The word "strong" has been replaced by "strongly" in the revised text.

Comment 17: Line 145: replace 'KY90' by 'the KY90'

Reply: The needful is done.

Comment 18: Line 148: replace 'other' by 'the other'

Reply: The needful is done.

Comment 19: Line 148: replace part after functions by: while results of all other functions (BD71, CL73 and KY90) are very similar to each other.

Reply: The text has been modified accordingly.

Comment 20: Line 164: The wording is not correct: I recommend replacing everywhere in the text (including captions) the formulation 'incorporated functions' by 'newly installed functions' (note that the default function is also an incorporated function in the model).

Reply: The word "incorporated" has been replaced by "newly installed" everywhere in the revised text.

Comment 21: Line 166: brackets are not correct (see above)

Reply: These are corrected in the modified text.

Comment 22: Line 185: replace 'of 1st' by 'of the first'

Reply: The needful is done.

Comment 23: Line 191: replace 'brief' by 'a brief ' and use better' given in' than stated in'

Reply: The needful is done.

Comment 24: Lines 199-201: Can these sublayers be explained briefly? Not every reader is an expert for this. E.g., what is dynamic convective-free convective?

Reply: The sublayers are explained briefly, and the modified text is presented here for reviewers' reference:

Lines 230-233…Note that the sublayers DNS ($-0.04 \le \zeta \le 0$) and DNS-DCS transition ($-0.12 \le \zeta < -0.04$) correspond to weakly to moderately unstable conditions, while sublayers DCS ($-1.20 \le \zeta < -0.12$), DCS-FCS ($-2.0 \le \zeta < -1.20$), and FCS ($\zeta < -2.0$) belong to moderately to strongly convective conditions (Srivastava and Sharan, 2015).

Comment 25: Line 218: This is now in contrast to the description in the preceding paragraph where it is written that differences are large.

Reply: The necessary changes are made.

Comment 26: Line 238: I guess it should be written almost identical, Identical results can only be achieved, when the same formula is used. This should be corrected at all occurrences.

Reply: The text has been modified accordingly throughout the manuscript.

References:

1. Carl, D. M., Tarbell, T. C., and Panofsky, H. A.: Profiles of Wind and Temperature from Towers over Homogeneous Terrain, J. Atmos. Sci., 30, 788-794, http://dx.doi.org/10.1175/1520-0469(1973)030<0788:POWATF>2.0.CO;2, 1973.
2. Kader, B. A., and Yaglom, A. M.: Mean Fields and Fluctuation Moments in Unstably Stratified Turbulent Boundary Layers, Journal of Fluid Mechanics, 212, 637–662, https://doi.org/10.1017/S0022112090002129, 1990.
3. Srivastava, P., and Sharan, M.: Characteristics of the Drag Coefficient over a Tropical Environment in Convective Conditions, J. Atmos. Sci., 72, 4903–4913, https://doi.org/10.1175/JAS-D-14-0383.1, 2015.
4. Srivastava, P., and Sharan, M.: Analysis of Dual Nature of Heat Flux Predicted by Monin-Obukhov Similarity Theory: An Impact of Empirical Forms of Stability Correction Functions, J. Geophys. Res. Atmos., 124, 3627–3646, https://doi.org/10.1029/2018JD029740, 2019.
5. Srivastava, P., and Sharan, M.: Uncertainty in the Parameterization of Surface Fluxes under Unstable Conditions, J. Atmos. Sci., 78, 2237–2247, https://doi.org/10.1175/JAS-D-20-0350.1, 2021.