Supplementary Material

An Updated Parameterization of the Unstable Atmospheric Surface Layer in WRF Modeling System

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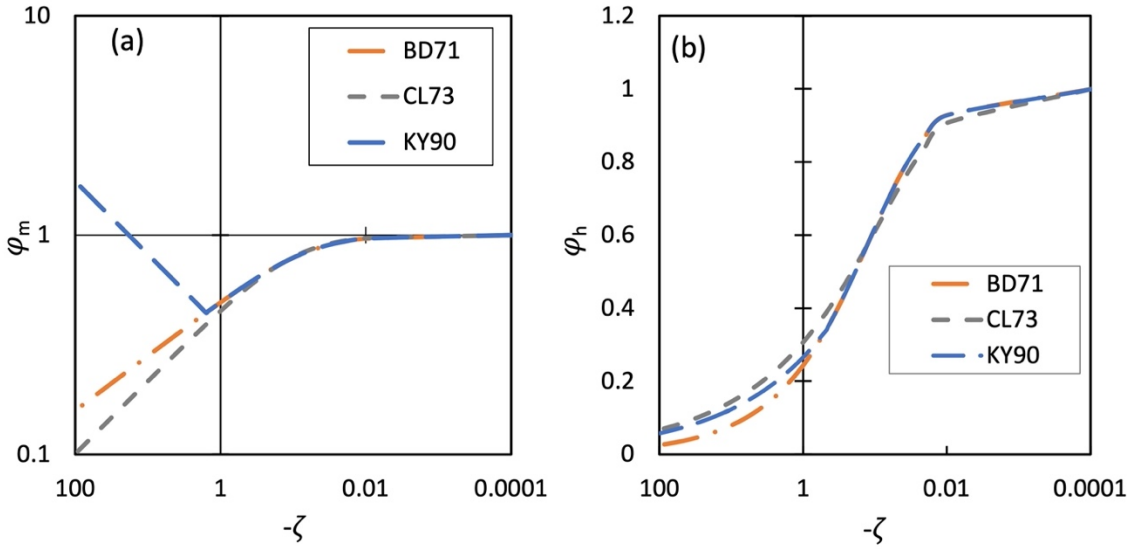

Figure S1. Variation of different functional forms of $\boldsymbol{\varphi_m}$ and $\boldsymbol{\varphi_h}$ with respect to $-\boldsymbol{\zeta}$ utilized in this study based on the different classes.

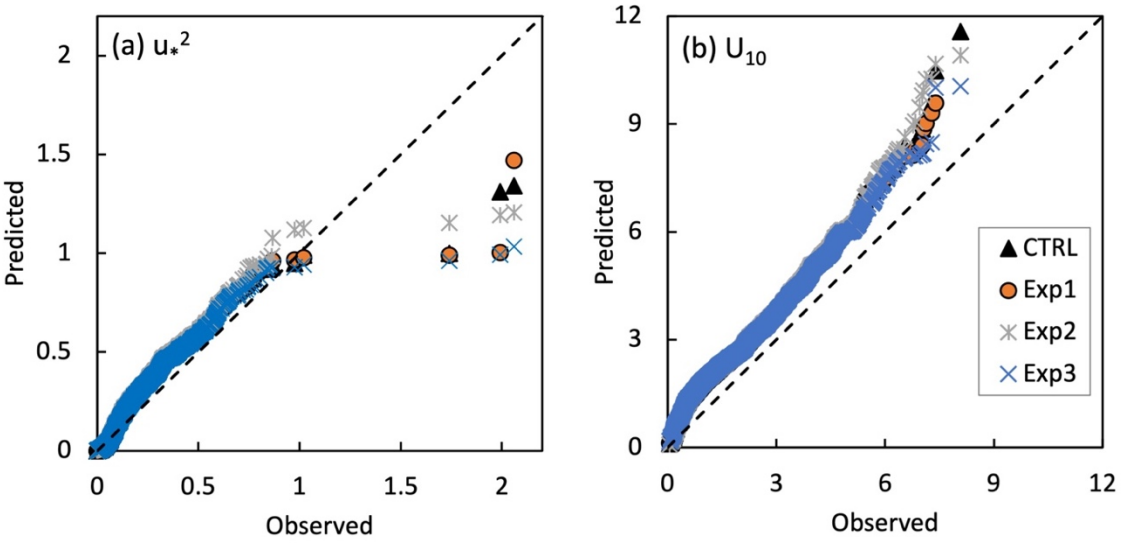

Figure S2. Q-Q plot for model simulated (a) $\boldsymbol{u_*^2}$, and (b) U_{10} from different experiments and CTRL simulation with respect to the observational data derived from the flux tower at Ranchi (India) during MAM season (2009).

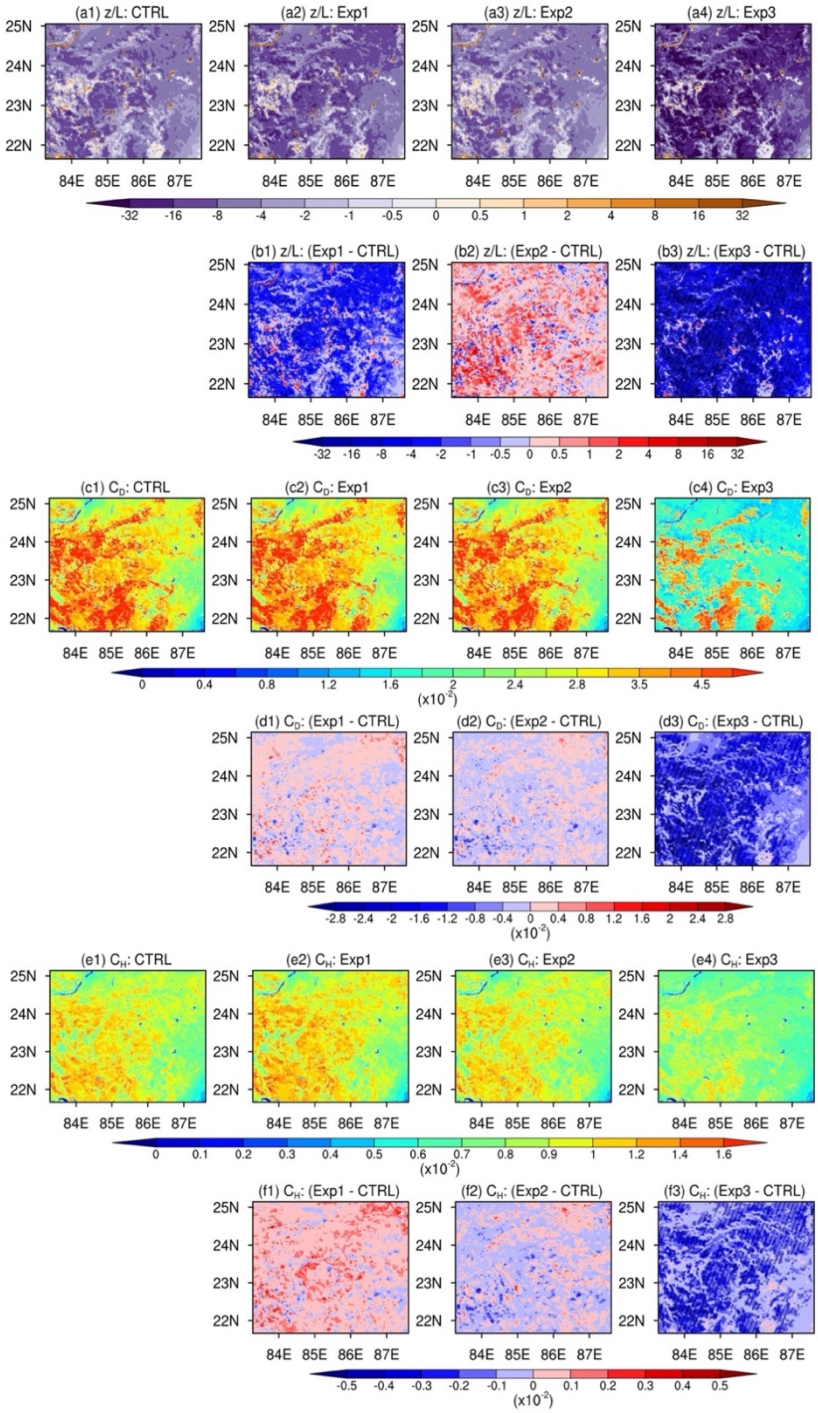

Figure S3. Mean spatial distribution of model simulated $\boldsymbol{\zeta}$ (1st row), $\mathbf{C_D}$ (2nd row) and $\mathbf{C_H}$ (3rd row) from different experiments and their differences with respect to CTRL simulation averaged during strong unstable conditions (hours during daytime in which $\boldsymbol{\zeta}$ is smaller than $\mathbf{-10}$) for whole simulation period. Hatched regions show significant differences at 95% confidence level in experiments with respect to CTRL simulation.

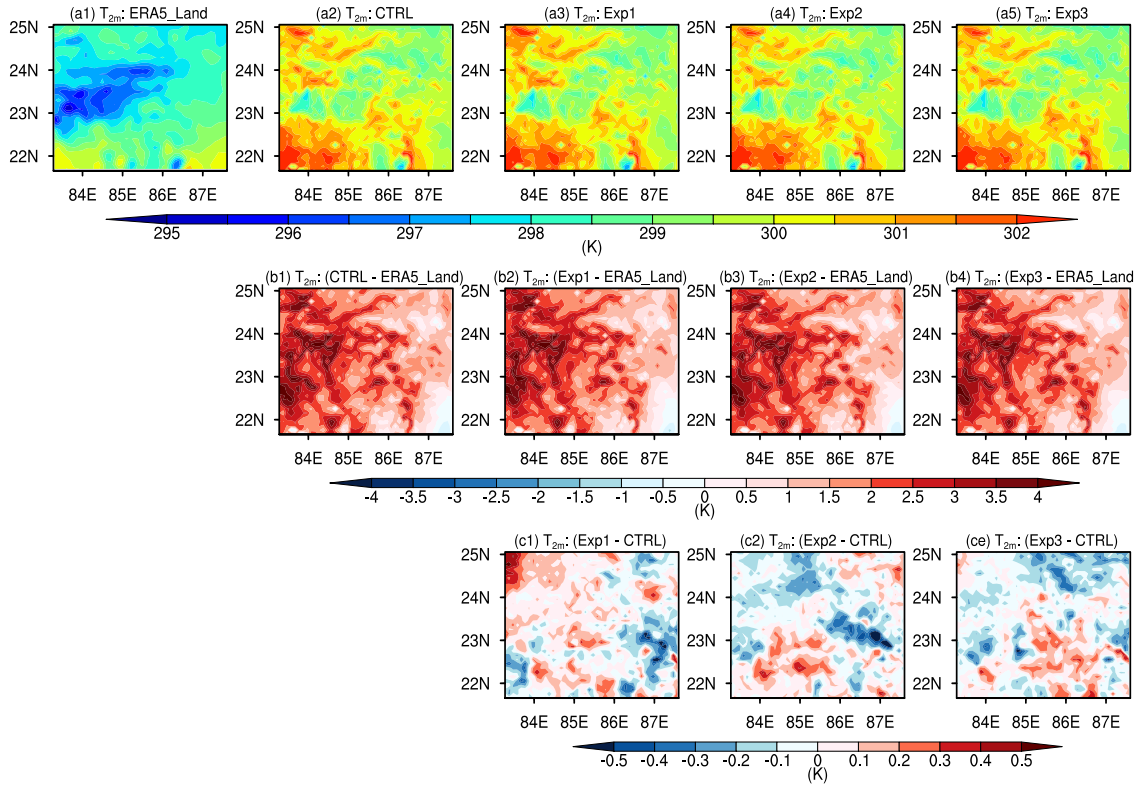

Figure S4. Mean spatial distribution of T_{2m} from ERA5 land reanalysis (a1) and simulated using different experiments (a2-a5) and their differences with respect to ERA5 land reanalysis data (b1-b4) averaged during strong unstable regime (hours during daytime in which $\boldsymbol{\zeta}$ is smaller than $\mathbf{-10}$) for whole simulation period. The differences between different experiments and CTRL simulation are shown in last row (c1-3).

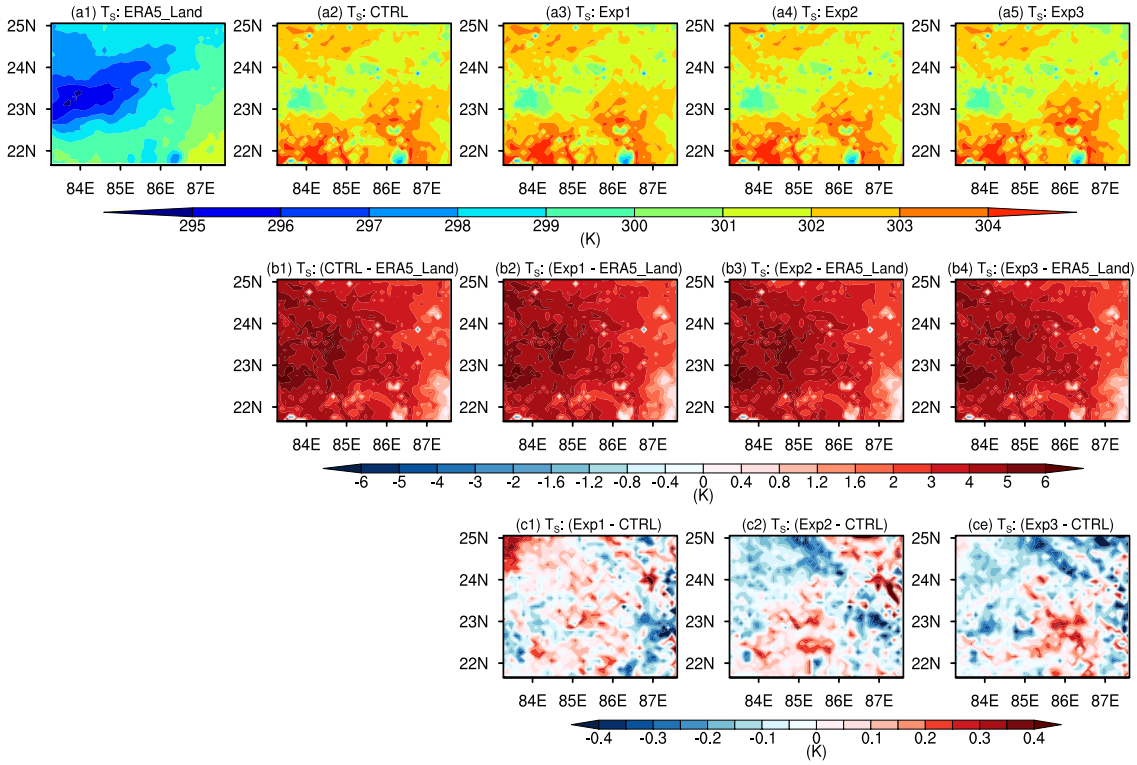

Figure S5. Same as Figure S4 but for T_S.

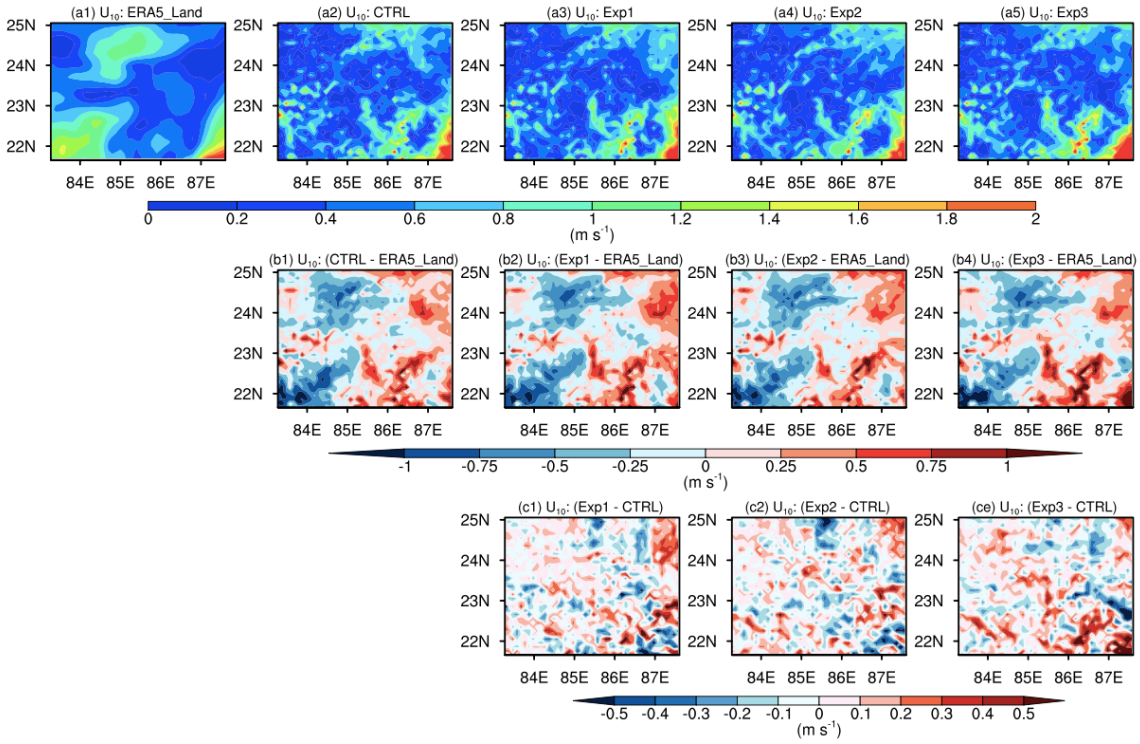

Figure S6. Same as Figure S4 but for U_{10}.

MAM		Bias (%)	RMSE	PCC
SHF (W m^{-2})	CTRL	7.089	37.373	0.471
	Exp1	7.040	37.416	0.471
	Exp2	7.124	37.439	0.469
	Exp3	7.171	37.419	0.475
LHF (W m^{-2})	CTRL	-33.543	50.698	0.385
	Exp1	-33.539	50.699	0.384
	Exp2	-33.584	50.722	0.387
	Exp3	-33.550	50.706	0.384
T_{2m} (K)	CTRL	0.244	1.264	0.720
	Exp1	0.242	1.258	0.720
	Exp2	0.244	1.263	0.720
	Exp3	0.246	1.267	0.719
T_S (K)	CTRL	0.506	2.754	0.503
	Exp1	0.508	2.755	0.501
	Exp2	0.510	2.761	0.504
	Exp3	0.502	2.752	0.512
U_{10} (m s^{-1})	CTRL	32.283	0.544	0.899
	Exp1	32.123	0.543	0.898
	Exp2	31.177	0.535	0.894
	Exp3	32.057	0.539	0.911

Table S1. Comparison statistics for SHF (W m^{-2}), LHF (W m^{-2}), T_{2m} (K), T_S (K), and U_{10} (m s^{-1}) simulated using different experiments together with CTRL simulation with respect to ERA5 land reanalysis data averaged during daytime for the entire simulation period. The mean bias (%), pattern correlation coefficient (PCC), and root mean square error (RMSE) are shown.