Research Article

Evaluation of Parameterization Schemes in the WRF Model for Estimation of Mixing Height

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This paper deals with the evaluation of parameterization schemes in the WRF model for estimation of mixing height. Numerical experiments were performed using various combinations of parameterization schemes and the results were compared with the mixing height estimated using the radiosonde observations taken by the India Meteorological Department (IMD) at Mangalore site for selected days of the warm and cold season in the years 2004–2007. The results indicate that there is a large variation in the mixing heights estimated by the model using various combinations of parameterization schemes. It was seen that the physics option consisting of Mellor Yamada Janjic (Eta) as the PBL scheme, Monin Obukhov Janjic (Eta) as the surface layer scheme, and Noah land surface model performs reasonably well in reproducing the observed mixing height at this site for both the seasons as compared to the other combinations tested. This study also showed that the choice of the land surface model can have a significant impact on the simulation of mixing height by a prognostic model.

1. Introduction

Prognostic atmospheric models are used as meteorological drivers to air pollution models in the absence of representative measured meteorological data for a site. These models generally provide wind speed, wind direction, temperature, humidity, rainfall, and mixing height values to the air pollution models. Many times, the resolution at which these models are integrated is too coarse to resolve the exchanges of heat, momentum, and moisture taking place at the air soil interface and hence these exchanges have to be parameterized in atmospheric models. Parameterization schemes may also be included in an atmospheric model for the representation of atmospheric phenomena whose explicit treatment may become too prohibitive due to cost and computer limitations. A weather model includes parameterizations for radiation, surface layer fluxes, turbulence, cumulus convection, and clouds. Generally there are six to seven schemes available for representation of each of these processes with its own merits and demerits depending upon the terrain, geography, and climate of the area under

consideration. Mixing height is an important input to air pollution models since the transport and extent of mixing of pollutants depend on it. The mixing in the atmosphere primarily takes place through convective and mechanical processes. During the daytime, differential heating due to solar radiation sets up strong thermals in the atmosphere and the convective processes dominate whereas, during the nighttime, mechanical processes are responsible for the turbulent mixing. The variation of mixing height with varying parameterization schemes was studied by other investigators also. For example, Shin and Hong [1] intercompared five Planetary Boundary Layer (PBL) schemes in the WRF model for a single day from the Cooperative Atmosphere Surface Exchange Study (CASES-99) field program. They reported a large variation in the mixing height values computed by the five schemes in the daytime and nighttime. Similarly Han et al. [2] had also evaluated five PBL schemes in the MM5 model for the East Asian domain for March 2001 and reported a large difference in the mixing heights predicted by the various combinations of parameterization schemes.

FIGURE 1: Model domains and the topography of the inner domain (red star denotes the plant site).

TABLE 1: Description of parameterization schemes.

Land surface	Surface layer	Planetary boundary layer	Combination
Thermal diffusion	Monin Obukhov	YSU	A
	Monin Obukhov	ACM2 (Pleim)	B
	Monin Obukhov (Janjic Eta)	Mellor Yamada Janjic (Eta)	D
	QNSE	QNSE	F
Noah land surface model	Monin Obukhov	YSU	C
	Monin Obukhov (Janjic Eta)	Mellor Yamada Janjic (Eta)	E

YSU: Yonsei University; ACM2: Asymmetric Convective Model version 2; QNSE: Quasi-Normal Scale Elimination.

Hu et al. [3] compared the 3-month mean diurnal variations of the simulated mixing heights using different combination of parameterization schemes in the WRF model with the observed values for South East Texas.

The present study focuses on the evaluation of parameterization schemes in the WRF model for estimation of mixing height for Kaiga site. Kaiga is one of the sites where nuclear power plants are operated for generation of electricity by Nuclear Power Corporation of India Ltd (NPCIL). It is a complex site with tall hills, evergreen forests, a reservoir, and so forth. Weather forecasting is important in the nuclear industry because of the aid it can provide in handling an emergency situation. However the weather forecast model needs to be validated/tuned with proper selection of parameterization schemes for it to be used in case of an emergency situation. Also many times a weather model is coupled with an offline atmospheric dispersion model for prediction of concentration. In order to validate the mixing height estimated by the WRF model, the radiosonde observations taken by the India Meteorological Department (IMD) are

utilized. Since radiosonde data for Kaiga site are not available, the radiosonde data from the nearby radiosonde observation station, Mangalore, are utilized for this purpose. The Mangalore station is at a distance of ~300 km from Kaiga site. It should be noted that the model values were also extracted at this location for comparison with observed values. The cases selected for simulation correspond to selected days in the warm and cool season. Description of the model domain, numerical experiments, WRF model set-up, and physics parameterizations used is given in Section 2 and the results are presented in Section 3.

2. Model and Methodology

The study domain covers south west India centered at the Kaiga Generating Station (KGS) ($14^{\circ}51'48''$ N, $74^{\circ}26'31''$ E) as shown in Figure 1. The WRF model version 3.1.1 (Skamarock et al. [4]; Wei et al. [5]) is integrated using three nested domains with grid spacing varying from 27 km, 9 km, and

TABLE 2: Description of experiments.

Simulation period	Case	Experiment
600Z 26 December 2004–00Z 29 December 2004	Minimum temperature	TMN1
00Z 17 January 2005–00Z 20 January 2005		TMN2
00Z 26 January 2006–00Z 29 January 06		TMN3
00Z 14 November 2007–00Z 17 November 07		TMN4
00Z 13 March 2004 –00Z 16 March 2004	Maximum temperature	TMX1
00Z 04 April 2005–00Z 07 April 2005		TMX2
00Z 23 February 2006–00Z 26 February 2006		TMX3
00Z 24 April 2007–00Z 27 April 2007		TMX4

TABLE 3: Comparison of model generated mixing height with the observed values for cases TMN1–TMN4.

	A (m)	B (m)	C (m)	D (m)	E (m)	F (m)	O (m)	Case study
12Z 26 December 2004	77	136	112	145	146	800	300	TMN1
00Z 27 December 2004	248	77	339	391	392	565	150	
12Z 27 December 2004	227	169	107	145	398	1069	300	
00Z 28 December 2004	405	159	546	395	393	2577	150	
12Z 28 December 2004	34	164	118	146	399	400	400	
00Z 29 December 2004	305	103	375	144	396	1064	100	
12Z 17 January 2005	256	293	493	401	808	580	900	TMN2
00Z 18 January 2005	29	33	30	145	145	144	350	
12Z 18 January 2005	112	189	297	1568	580	2073	600	
00Z 19 January 2005	30	38	32	145	144	144	200	
12Z 19 January 2005	215	213	360	400	806	807	700	
00Z 20 January 2005	159	50	30	144	145	144	100	
12Z 26 January 2006	350	258	417	146	575	575	550	TMN3
00Z 27 January 2006	133	53	115	142	142	253	100	
12Z 27 January 2006	237	192	236	146	399	258	650	
00Z 28 January 2006	121	39	234	394	143	1540	100	
00Z 29 January 2006	232	84	269	142	252	2041	200	
00Z 14 November 2007	309	203	347	145	398	397	200	TMN4
12Z 14 November 2007	137	54	171	142	143	253	100	
00Z 15 November 2007	133	206	105	146	146	258	100	
12Z 15 November 2007	101	57	29	142	143	565	480	
00Z 16 November 2007	35	231	202	145	145	395	100	
12Z 16 November 2007	40	37	29	141	141	787	400	
	3/23	3/23	1/23	1/23	13/23	2/23		

The bold values refer to the best match between model and observation.

3 km. The terrain and land use data for the innermost domain with 3 km grid resolution were taken from 30' data, for domain with 9 km resolution from 5' data and for the domain with 27 km resolution from 10' data available from the United States Geological Survey (USGS). The parameterization schemes tested in this study are defined in Table 1. The PBL schemes tested are Yonsei University, (YSU, Hong et al. [6]), Mellor Yamada Janjic Eta (MYJ, Janjic [7, 8]), Asymmetric Convective Model, (ACM2, Pleim [9]), and Quasi Normal Scale Elimination (QNSE, Sukoriansky et al. [10, 11]). The surface layer (SL) schemes used are Monin Obukhov (Monin and Obukhov [12]), Monin Obukhov Janjic Eta (MYJ, Monin and Obukhov [12], Janjic [13]), and Quasi-Normal Scale

Elimination (QNSE, Sukoriansky et al. [10, 11]) and the land surface models (LSM) used are thermal diffusion (Dudhia [14]) and the Noah land surface model (Chen and Dudhia [15]). The other physical parameterizations are identical for all experiments which are Rapid radiation Transfer Model for long-wave radiation (RRTM, Mlawer et al. [16]), Dudhia (Dudhia [17]) for short-wave radiation, Kain Fritsch scheme for cumulus parameterization (Kain and Fritsch [18], J. S. Kain [19]) and Ferrier new Eta (Ferrier et al. [20]) scheme for representing microphysical processes in the clouds. A total of six combinations of parameterization schemes are considered which are defined in the Table 1. The National Centers for Environmental Prediction (NCEP) Final Analysis data

TABLE 4: Comparison of model generated mixing height with the observed values for cases TMX1–TMX4.

	A (m)	B (m)	C (m)	D (m)	E (m)	F (m)	O (m)	Case study
12Z March 2004	256	293	493	401	808	580	900	TMX1
00Z 14 March 2004	29	33	30	145	145	144	350	
12Z 14 March 2004	112	189	297	1568	580	2073	900	
00Z 15 March 2004	30	38	32	145	144	144	200	
12Z 15 March 2004	215	213	360	400	806	807	700	
00Z 16 March 2004	159	50	30	144	145	144	100	
12Z 04 April 2005	257	365	399	580	809	809	900	TMX2
00Z 05 April 2005	30	39	30	145	146	145	150	
12Z 05 April 2005	86	237	338	1575	581	2084	900	
00Z 06 April 2005	30	59	30	145	146	145	350	
12Z 06 April 2005	117	272	226	147	403	587	800	
00Z 07 April 2005	30	39	30	146	147	259	300	
12Z 23 February 2006	117	153	276	146	577	580	600	TMX3
00Z 24 February 2006	89	35	42	144	143	1062	100	
12Z 24 February 2006	84	1017	206	146	576	2058	400	
00Z 25 February 2006	134	86	29	143	571	254	100	
12Z 25 February 2006	331	223	355	398	575	398	900	
00Z 26 February 2006	198	52	29	395	144	2049	100	
12Z 24 April 2007	429	409	533	811	809	1083	800	TMX4
00Z 25 April 2007	30	53	41	145	579	258	150	
12Z 25 April 2007	214	263	350	588	584	819	700	
00Z 26 April 2007	58	54	30	147	146	261	50	
12Z 26 April 2007	422	436	443	585	585	1088	900	
00Z 27 April 2007	30	57	30	146	146	260	100	
No. of successes	—	2/24	—	1/24	18/24	3/24		

The bold values refer to the best match between model and observation.

available at 6 hourly interval on a $1^\circ \times 1^\circ$ resolution are used to supply initial and boundary conditions. The model uses two-way nested boundary conditions and they are updated every 6 hours. A total of eight simulation cases are considered in the present study which are based on either maxima or minima in temperature and these are described in Table 2. This study focuses on the comparison of mixing height estimated by the model in the various combinations of parameterization schemes with the observed values. Each simulation is for a three-day period one on the day of occurrence, one day prior, and one day later to it. The mixing height computation by the model differs according to the PBL scheme used. The schemes YSU and ACM2 estimate mixing height based on the Richardson number whereas the remaining two PBL schemes namely MYJ and QNSE diagnose the mixing height on the basis of the turbulent kinetic energy (TKE). While both the approaches may be theoretically correct, the one which produces values of mixing height which compare well with the observation can be considered to be the better approach. In addition to the model's own diagnosis of mixing height, the temperature profile given by the model was also used to estimate the mixing height based on the Holtzworth [21] method. In this case, the variation between different combinations of schemes due to varying methodologies is

eliminated and the differences observed are only due to those in the temperature profile of the model. Both the methods of estimating mixing height are in turn compared with the observation.

3. Results and Discussion

The mixing heights obtained in all combinations of parameterization schemes tested are shown in Tables 3 and 4 for the experiments TMN1–TMN4 and TMX1–TMX4, respectively, with the best performing combinations presented in bold font. The observed mixing heights are calculated from the radiosonde temperature profile following the method of Holtzworth [21]. For a three-day simulation, six radiosonde profiles are available for comparison (one each at 00Z and 12Z). However, sometimes, a particular sounding may not be available and hence that time is not considered in the analysis for example, 12Z on January 28, 2006. In order to remove the dependence of mixing height on parameterization schemes, the mixing height values are also generated by using Holtzworth method on the model derived temperature profiles and the results are presented in Table 5 for experiments TMN1–TMN4 and in Table 6 for experiments TMX1–TMX4.

TABLE 5: Comparison of model generated mixing height (using Holtzworth's method) with the observed values for experiments TMN1–TMN4.

	A (m)	B (m)	C (m)	D (m)	E (m)	F (m)	O (m)	Case study
12Z 26 December 2004	1300	1400	550	1200	450	1250	300	TMN1
00Z 27 December 2004	100	100	—	150	50	200	150	
12Z 27 December 2004	1350	1300	650	1300	400	1450	300	
00Z 28 December 2004	—	80	—	50	80	—	150	
12Z 28 December 2004	1100	800	500	1200	500	1300	400	
00Z 29 December 2004	—	80	—	70	80	50	100	
12Z 17 January 2005	600	600	600	580	550	625	900	TMN2
00Z 18 January 2005	200	180	200	150	100	150	350	
12Z 18 January 2005	1300	1200	1000	1400	950	1350	600	
00Z 19 January 2005	250	300	150	200	100	250	200	
12Z 19 January 2005	1100	1050	900	1150	850	1150	700	
00Z 20 January 2005	200	200	80	150	80	200	100	
12Z 26 January 2006	1400	1800	1050	2000	900	2000	550	TMN3
00Z 27 January 2006	50	200	50	200	100	200	100	
12Z 27 January 2006	1450	950	750	1400	700	1400	650	
00Z 28 January 2006	50	50	—	50	100	100	100	
00Z 29 January 2006	100	80	—	100	80	120	200	
00Z 14 November 2007	150	—	—	—	—	—	200	TMN4
12Z 14 November 2007	550	650	750	1250	600	1300	100	
00Z 15 November 2007	50	120	—	120	100	180	100	
12Z 15 November 2007	500	490	400	900	700	950	480	
00Z 16 November 2007	110	120	50	150	100	200	100	
12Z 16 November 2007	1250	1100	1000	1200	900	1200	400	
No. of successes	2/23	1/23	1/23	2/23	16/23	1/23		

The bold values refer to the best match between model and observation.

Here also, the best performing combinations are presented in bold font. The Holtzworth method works on the basis of intersection of the temperature profile with the dry adiabatic line drawn from the surface with the maximum temperature of the day for the 12Z mixing height and with the minimum temperature +5°C for the 00Z mixing height. In cases where the two curves do not intersect, the mixing height cannot be determined. These are represented by a “—” in Tables 5 and 6. The model derived mixing heights are shown in columns A–F and the observed mixing height is presented in column O. From Tables 3 and 4, one can estimate the magnitude of variation among the different parameterization schemes for estimation of mixing height at a given time making a parametric study so very essential. The differences in the model estimates of mixing height arise because of the various methods of calculation used in the schemes. For example at 12Z 26th December 2004, the observed mixing height from the radiosonde data was 300 m. The model generated values range from 77 m to 800 m indicating a large variation as compared to the observation. Similar variation is noted at other times also. It is also important to note the role of the land surface model in estimation of mixing height. In an atmospheric model, the land surface model is used to calculate the exchange coefficients of heat, momentum, and moisture at the air soil interface which is used in the estimation of heat, momentum, and moisture fluxes. These

fluxes provide the lower boundary condition for vertical transport in the PBL. The five-layer thermal diffusion model is a simple soil temperature model. The layers are 1 cm, 2 cm, 4 cm, 8 cm, and 16 cm thick. Below this the temperature is fixed at a deep layer average value. The soil moisture values are season dependent constant values based on land use categorization without considering the effects of vegetation. The Noah land surface model on the other hand predicts soil temperature and moisture in 4 layers extending 10 cm, 30 cm, 60 cm, and 100 cm from the surface and summing up to 2 m below the surface. It includes land use, monthly vegetation fraction, and evapotranspiration in the estimation of sensible and latent heat fluxes. In general, it is seen that the values of mixing height obtained using the Noah land surface model are better than those obtained with the thermal diffusion model for identical combinations of PBL/SL schemes (i.e., E is better than D and C is better than A) due to better representation of physical processes leading to transfer of heat, momentum, and moisture at the air soil interface. In fact Stensrud [22] says that “if variations in surface conditions occur over small scales, then the resulting rapid horizontal changes in the values of surface fluxes can lead to the development of non-classical mesoscale circulations, such as vegetation or inland sea breezes.” The model's representation of such processes are important for weather prediction for a complex terrain sites. For a given land surface model,

TABLE 6: Comparison of model generated mixing height (using Holtzworth method) with the observed values for experiments TMX1–TMX4.

	A (m)	B (m)	C (m)	D (m)	E (m)	F (m)	O (m)	Case study
12Z 13 March 2004	1200	950	950	1200	920	1450	900	TMX1
00Z 14 March 2004	220	150	250	250	200	200	350	
12Z 14 March 2004	350	300	500	900	500	950	900	
00Z 15 March 2004	150	180	180	200	200	250	200	
12Z 15 March 2004	1150	950	800	1450	750	1400	700	
00Z 16 March 2004	300	200	100	300	100	400	100	
12Z 04 April 2005	950	950	950	1300	900	1300	900	TMX2
00Z 05 April 2005	100	200	350	250	300	250	150	
12Z 05 April 2005	100	—	500	700	550	800	900	
00Z 06 April 2005	250	180	100	200	180	200	350	
12Z 06 April 2005	300	400	200	250	300	250	800	
00Z 07 April 2005	200	300	200	200	150	200	300	
12Z 23 February 2006	1050	1150	750	1600	700	1600	600	TMX3
00Z 24 February 2006	—	100	80	80	—	100	100	
12Z 24 February 2006	1400	1300	700	1500	600	1500	400	
00Z 25 February 2006	80	150	50	80	80	150	100	
12Z 25 February 2006	1300	1350	950	1450	850	1450	900	
00Z 26 February 2006	—	50	50	80	50	150	100	
12Z 24 April 2007	700	700	750	700	750	700	800	TMX4
00Z 25 April 2007	100	120	200	150	150	200	150	
12Z 25 April 2007	400	350	450	400	450	500	700	
00Z 26 April 2007	50	100	80	80	50	150	50	
12Z 26 April 2007	800	700	700	1050	700	1100	900	
00Z 27 April 2007	120	100	120	100	120	180	100	
No. of successes	2/24	3/24	—	2/24	15/24	2/24	—	

The bold values refer to the best match between model and observation.

TABLE 7: Statistical analysis.

Statistic	TMN_E	TMN_HE	TMX_E	TMX_HE
AVG.WRF (m)	318	385	423	415
AVG.O (m)	320	320	498	493
MAE (m)	123	159	179	125
IOA	0.86	0.83	0.84	0.91
CORR	0.74	0.76	0.75	0.86
RMSE (m)	160	222	229	186

AVG.WRF: average of model, AVG.O: average of observation, MAE: mean absolute error, IOA: index of agreement, CORR: correlation coefficient, RMSE: root mean square error, TMN_E: experiments TMN1–TMN4, TMN_HE: experiments TMN1–TMN4 but using Holtzworth method, and TMX_E, TMX_HE: same as TMN_E, TMN_HE for the case studies TMX1–TMX4.

say the Noah LSM, the results with the Monin Obukhov (Janjic Eta) PBL scheme and the Mellor Yamada Janjic (Eta) surface layer scheme are better than those with the YSU PBL and Monin Obukhov surface layer scheme (i.e., E is better than C). Hence it is seen that it is a combined effect of all parameterization schemes which translates into a good simulation of mixing height by an atmospheric model. As already mentioned, the Holtzworth method was also used to estimate the mixing height based on the model derived temperature profile under various combinations of parameterization schemes. For a comparison of the two methods, the scatter plots of the model generated mixing heights with the observations are shown in Figures 2 and 3 for the case

studies TMN1–TMN4 and TMX1–TMX4, respectively. Also, many statistical parameters like average of model, average of observation, mean absolute error, index of agreement, and root mean square error were computed and are presented in Table 7. From Figure 2, it is seen that the model's own diagnosis of mixing height is underpredicted whereas the same obtained using Holtzworth method on the model generated temperature profile is overpredicted. However the Holtzworth method used on the model derived temperature profile has a smaller intercept as compared to that of the model's own diagnosis of mixing height. The correlation coefficient and index of agreement obtained in both the cases are comparable. From Table 7, referring to the errors, namely,

FIGURE 2: Comparison of model generated (in combination E) mixing height with the observed values for experiments TMN1-TMN4.

FIGURE 3: Comparison of model generated (in combination E) mixing height with the observed values for experiments TMX1-TMX4.

mean absolute and root mean square error, it is seen that the model's own estimation of mixing height is better than that obtained using the Holtzworth method on the model generated temperature profile on the basis of lower values of errors. The difference in the mean absolute error between the two methods is ~12% in an average mixing height of 320 m. Hence making a definite statement about any of the two methods being superior is not possible for the case studies TMN1-TMN4 based on the current simulations carried out. Similar analysis was done for the case studies TMX1-TMX4 also, with the scatter plot being shown in Figure 3. From the

plot and the statistical analysis in Table 7, it can be concluded that for these cases, the mixing height computed using the Holtzworth method on the model generated temperature profile is better than the model's own estimation of mixing height based on the turbulent kinetic energy. All the statistical parameters computed for the case TMX.HE (referring to Holtzworth method on the model derived temperature profile for experiments TMX1-TMX4) are superior to the case TMX.E (referring to experiments TMX1-TMX4). From Table 4, it is seen that on many occasions the mixing height at 12Z is underestimated by the model. Even if the land surface model chosen accounts for the physical processes occurring in the atmosphere, the coefficients/constants being used in the respective algorithms may require further refinement. When the Holtzworth method is applied on the model derived temperature profile in combination E, this underestimation is eliminated. Hence for the experiments TMX1-TMX4 corresponding to selected days in the warm season, the mixing height estimated using the Holtzworth method on the model derived temperature profile is better than the model's own estimation of mixing height. It is also to be noted that the application of the Holtzworth method on other combinations of parameterization schemes A, B, D, and F in this study leads to deterioration of model results and should be avoided. Finally to summarize, this study has shown that the set of parameterizations schemes defined by the combination E gives reasonable results for 13 out of 23 case studies for the cool season and 18 out of 24 case studies for the warm season mainly due to the Noah land surface model used. Nevertheless, this mixing height should still be verified by using the Holtzworth method on the model derived temperature profile obtained using the same combination of parameterization schemes for those locations where radiosonde data are available. This study also shows that the state-of-the-art parameterizations schemes in the WRF model still have scope for improvement.

Index of agreement

$$IOA = 1 - \frac{\sum_{i=1}^N (P_i - O_i)^2}{\sum_{i=1}^N (|P_i - O_{\text{mean}}| + |O_i - O_{\text{mean}}|)^2}. \quad (1)$$

Pearson correlation coefficient

$$\begin{aligned} \text{CORR} = & \left(N \left(\sum_{i=1}^N O_i P_i \right) - \left(\sum_{i=1}^N O_i \right) \left(\sum_{i=1}^N P_i \right) \right) \\ & \times \left(\left[N \left(\sum_{i=1}^N O_i^2 \right) - \left(\sum_{i=1}^N O_i \right)^2 \right] \right. \\ & \times \left. \left[N \left(\sum_{i=1}^N P_i^2 \right) - \left(\sum_{i=1}^N P_i \right)^2 \right] \right)^{-1/2}. \end{aligned} \quad (2)$$

Mean absolute error

$$\text{MAE} = \frac{1}{N} \sum_{i=1}^N |P_i - O_i|. \quad (3)$$

Root mean square error

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^N (P_i - O_i)^2}. \quad (4)$$

4. Conclusions

The numerical experiments carried out for the selection of the optimum combination of parameterization schemes for estimation of mixing height have shown that the physics option consisting of Mellor Yamada Janjic (Eta) as the PBL scheme, Monin Obukhov Janjic (Eta) as the Surface Layer scheme, and Noah land surface model performs reasonably well in reproducing the observed mixing height for almost all the cases considered for simulation as compared to the other combinations tested. The role played by the land surface model for a good simulation of mixing height was also emphasized. The application of the Holtzworth method on the model derived temperature profile to estimate mixing height as opposed to the model diagnosed mixing height suggests that during the warm season, the model derived mixing height based on the Holtzworth method matches reasonably well with the observations as opposed to the model diagnosed mixing height. However, for the cold season no such conclusive statement can be made. Such studies on the proper choice of parameterization schemes at a power plant site are useful when a prognostic weather model like WRF is to be coupled with an air quality model for atmospheric dispersion studies.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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