



Assessment of a surface-layer parameterization scheme in an atmospheric model for varying meteorological conditions

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Abstract. The performance of a surface-layer parameterization scheme in a high-resolution regional model (HRM) is carried out by comparing the model-simulated sensible heat flux (H) with the concurrent in situ measurements recorded at Thiruvananthapuram (8.5° N, 76.9° E), a coastal station in India. With a view to examining the role of atmospheric stability in conjunction with the roughness lengths in the determination of heat exchange coefficient (C_H) and H for varying meteorological conditions, the model simulations are repeated by assigning different values to the ratio of momentum and thermal roughness lengths (i.e. z_{0m}/z_{0h}) in three distinct configurations of the surface-layer scheme designed for the present study. These three configurations resulted in differential behaviour for the varying meteorological conditions, which is attributed to the sensitivity of C_H to the bulk Richardson number (Ri_B) under extremely unstable, near-neutral and stable stratification of the atmosphere.

Keywords. Meteorology and atmospheric dynamics (mesoscale meteorology; tropical meteorology; turbulence)

1 Introduction

Atmospheric surface-layer processes strongly influence the general circulation of the atmosphere (Businger et al., 1971). Most of the atmospheric models used for the numerical weather prediction (NWP) do not have fine resolutions to resolve such processes very precisely, and therefore a parametric representation (parameterization) is adopted in real practice (Stensrud, 2007). The exchange processes between the atmosphere and the underlying earth's surface are dominated by the turbulent fluxes which play key roles in determining the vertical structure and energetic balance of the

entire atmosphere through redistributing heat and moisture. These processes in the NWP models are quantified through the surface-layer parameterization schemes which indirectly control the atmospheric boundary layer (ABL) growth and other physical processes such as the intensity of moist convection and low-level cloudiness. These parameterization schemes are responsible for the partitioning of incoming solar radiation at the surface into sensible, latent and ground (soil) heat fluxes through determination of the bulk exchange coefficients and also in influencing the soil wetness and near-surface temperature (Anurose and Subrahmanyam, 2013). The bulk exchange coefficients for momentum, heat and moisture in most of these schemes are empirically related as functions of the roughness lengths and atmospheric stability. Thus, in a majority of surface-layer parameterization schemes, an appropriate representation of the roughness lengths and atmospheric stability is assumed to be a critical component. At the same time, it is equally important that the prevailing meteorological conditions are fairly represented in the NWP model in question, and this particular aspect is being addressed in the present research article. Different regimes of the atmospheric flow stability and their impacts on the exchange processes are generally defined through integrated form of stability functions for the unstable and stable stratification. On the other hand, the roughness length for momentum (z_{0m}), heat (z_{0h}) and moisture (z_{0q}) are taken as the key parameters for representing the surface morphology, terrain characteristics, and its heterogeneity (Brutsaert, 1975). In the early years, roughness lengths for momentum, heat and moisture (z_{0m} , z_{0h} and z_{0q}) were treated in an identical fashion by considering the Reynolds analogy (Louis, 1979; Garratt, 1992). In the last few years, a number of surface-layer parameterization schemes have

been developed in which the stability functions and exchange coefficients appear to have different forms (Paulson, 1970; Businger et al., 1971; Dyer, 1974; Louis, 1979; Beljaars and Holtslag, 1991). Later, many researchers reported that the ratio between momentum and thermal roughness lengths (i.e. z_{0m}/z_{0h}) cannot be taken as unity especially for a heterogeneous terrain as the Reynolds analogy for such cases are no longer valid (Owen and Thomson, 1963; Garratt and Hicks, 1973; Brutsaert, 1975, 1982; Garratt, 1978; Hopwood, 1995; Mahrt, 1996; Chen et al., 1997). Van Den Hurk and Holtslag (1997) made a detailed comparison between various surface-layer parameterization schemes for the estimation of bulk transfer coefficients for a wide range of stability and numerous values of z_{0m} and z_{0h} respectively. Kot and Song (1998) also showed the impact of varying stability conditions and surface types on the estimation of bulk transfer coefficients and turbulent fluxes. Results obtained from many of these studies highlighted the limitations of surface-layer parameterization schemes and their applicability for a wide range of stability and roughness length ratios. Thus, it is extremely important to understand the relative impacts of these factors on the estimation of bulk transfer coefficients and turbulent fluxes in NWP models especially over a heterogeneous terrain.

In the present study, we investigate the performance of a surface-layer parameterization scheme based on the bulk formulations suggested by Louis (1979) in a high-resolution regional model (HRM) centred around Thiruvananthapuram (8.5° N, 76.9° E), India, for varying meteorological conditions. Local weather over the heterogeneous terrain around this coastal station is influenced by the diurnal variations within the ABL and also by the large-scale monsoonal wind flow (Ramachandran et al., 1994; Nair et al., 2011), thereby making this experimental site an ideal platform for investigating the role of atmospheric stability and its impacts on the quantification of surface exchange processes through parameterization. The main objective of this research work is to address the relative dominance of the atmospheric stability with respect to the z_{0m}/z_{0h} ratio in terms of their representation in the Louis (1979) parameterization scheme. The study also explains the sensitivity of z_{0m}/z_{0h} ratio in the derivation of bulk transfer coefficients for varying meteorological conditions over Thiruvananthapuram.

2 Model details and experiments

HRM is a hydrostatic atmospheric model developed at Deutscher Wetterdienst of Germany and is extensively utilized for NWP applications at meso- α and meso- β scales (Majewski et al., 2002; Ramachandran et al., 2006; Rani et al., 2010; Subrahmanyam et al., 2012b; Anurose and Subrahmanyam, 2013). With the advancement in monitoring techniques of atmospheric features at a very fine spatial resolution from various satellites and availability of an

increased number of ground-based in situ observations, the horizontal grid resolutions of the global models are consistently decreasing from coarser grids to finer grids. Subsequently, a majority of the NWP models are adopting a non-hydrostatic approximation, which can account for the physical processes associated with the vertical velocities in a better manner. In this process, the HRM model is also under a transition from a hydrostatic approximation to a completely non-hydrostatic approximation. However, in the present study, as the database is confined to year 2010, we have adopted the hydrostatic approximation. In the default configuration of HRM model, the initial and lateral boundary conditions are extracted from the interpolation of analyses and forecast fields respectively of the German global model (Subrahmanyam et al., 2012b). The analyses and forecast fields of the global model for the present study period were available at a spatial resolution of 0.30°, and the land-sea boundaries were clearly identified through land fraction database. Similarly, the topographical features and associated heterogeneity is well addressed through various single- and multi-level atmospheric fields, together with multi-level soil fields in the HRM model (Subrahmanyam et al., 2012b). The exchange processes between the earth's surface and the lowest part of the atmosphere in this model are treated through a surface-layer parameterization scheme based on Louis (1979) (hereafter referred to as the L-79 scheme) in the Prandtl layer and a diagnostic level-two scheme based on Mellor and Yamada (1974) for the ABL and the free atmosphere. In the Louis (1979) parameterization scheme, the iterative solutions for the bulk exchange coefficients are approximated by analytical functions which relate these coefficients to the roughness lengths, the height within the surface layer and the bulk Richardson number (Ri_B) as a practical stability parameter. The dynamic stability of the atmosphere is represented through Ri_B whose magnitudes are used for discriminating the turbulent flow from the laminar flow (Subrahmanyam et al., 2012a). This is indeed in accordance with the recent theoretical and laboratory research works which suggest a transformation of the laminar flow to a turbulent flow at $Ri_B > 0.25$. However, the termination of turbulence takes place at much higher static stability with $Ri_B > 1$; intermittent turbulence may occur at even higher stabilities. Based on several observational evidence, Arya (2001) has shown that the turbulent flow often stays turbulent even for Ri_B as large as 1.0. For exact representation of the laminar flow in NWP models, the bulk exchange coefficients are assumed to vanish in the surface-layer parameterization schemes. However, this would completely decouple the atmosphere from the surface, resulting in a detrimental impact on the low-level flow structure. For avoiding such cases, the stability functions are chosen such that a critical value of Ri_B is not involved and the bulk exchange coefficients asymptotically approach zero with increasing static stability. In the case of the L-79 scheme, analytical expressions for the heat exchange coefficient (C_H) are derived separately for the

unstable and stable conditions (Louis, 1979). For unstable conditions of the atmosphere, characterized with $Ri_B < 0$,

$$C_H = C_{Hn} \cdot \left[1 + \left(\frac{3 \cdot b \cdot |Ri_B|}{1 + 3 \cdot b \cdot c \cdot C_{Hn} \cdot \left\{ \left(\frac{h}{z_{0h}} \right)^{\frac{1}{3}} - 1 \right\}^{\frac{3}{2}} \cdot \sqrt{|Ri_B|}} \right)^2 \right] \tag{1}$$

whereas in the case of stable atmosphere, characterized by $Ri_B \geq 0$,

$$C_H = C_{Hn} \cdot \left[\frac{1}{1 + 3 \cdot b \cdot Ri_B \cdot (1 + d \cdot Ri_B)^{\frac{1}{2}}} \right] \tag{2}$$

where the neutral stability transfer coefficient for heat (C_{Hn}) is uniquely related to the z_{0m} and z_{0h} ,

$$C_{Hn} = \kappa^2 \cdot \left\{ \ln \left(\frac{h}{z_{0m}} \right) \right\}^{-1} \cdot \left\{ \ln \left(\frac{h}{z_{0h}} \right) \right\}^{-1} \tag{3}$$

In the above expressions, κ is the von Karman constant and $b = c = d = 5.0$ and h (= 10 m, corresponding to the lowest level of the HRM model) is the measurement height. From the expressions for C_H described above for varying stability conditions, it is obvious that the roughness lengths for momentum and heat in conjunction with the Ri_B play a crucial role in the determination of surface-layer turbulent fluxes.

A recent study carried out by Anurose and Subrahmanyam (2013) on the performance of the L-79 scheme emphasized the need of a critical assessment of the treatment of roughness lengths for momentum and heat. Results obtained from their study suggested a differential treatment of z_{0m} and z_{0h} in the original L-79 scheme for its improved performance over the heterogeneous terrain. In the present study, the HRM model simulations are carried out with three distinct configurations of the surface-layer parameterization scheme (namely, L-79, L-100 and L-diurnal) following the modifications suggested by Anurose and Subrahmanyam (2013). In the L-79 scheme, z_{0m} and z_{0h} are treated in an identical fashion assuming $z_{0m} = z_{0h}$. In the L-100 configuration, the z_{0m}/z_{0h} ratio is set to 100, whereas it is subjected to a diurnal variations in accordance with the equation shown in Table 1 for the L-diurnal configuration. These alterations in the z_{0m}/z_{0h} ratio are activated for the land regimes only, and the oceanic part is kept unaltered in all the three sets of simulations (Anurose and Subrahmanyam, 2013). The HRM model simulations are carried out for the generation of +24h forecast fields using the L-79, L-100 and L-diurnal configurations of the surface-layer parameterization scheme respectively. The initial conditions for all these simulations are extracted from the analyses of GME, a German global model, corresponding to 00:00 UTC, whereas the lateral boundary conditions are derived from the forecast fields of GME at +3 hourly intervals.

Table 1. Technical details on the HRM configuration used for the present study.

Model component	Description
Model domain (longitudinal coverage)	74.5–79.5° E
(latitudinal coverage)	6.0–11.0° N
Horizontal resolution	0.0625°
Vertical levels	60 levels with vertical stretching
Radiation	δ -two stream radiation scheme including long-wave and short-wave fluxes
Surface-layer parameterization	Based on Louis (1979) scheme and subsequently modified by Anurose and Subrahmanyam (2013)
(a) L-79 (default configuration)	$z_{0m} = z_{0h}$
(b) L-100	$z_{0m}/z_{0h} = 100$
(c) L-diurnal	$\ln \left\{ \frac{z_{0m}}{z_{0h}} \right\} = \xi - \left \frac{T - T_{peak}}{2} \right $ where $T_{peak} = 12:00$ UTC and $\xi = 6.0$
Convection	Mass flux convection scheme

3 Classification of the database

An automatic weather station (AWS) equipped with slow-response sensors is used for accessing the prevailing meteorological conditions over the experimental site of Thiruvananthapuram. Beside the routine meteorological measurements through AWS, one sonic anemometer placed at an altitude of 10 m above the mean sea level provided fast-response in situ measurements of three-axis wind components and near-surface air temperatures, which are later used for the estimation of H . The database extends for a period of 1 year spanning from January 2010 to December 2010. In the months of December to February (also termed as the winter monsoon), this experimental site experiences typically dry season with mostly clear-sky days. In contrast to the winter monsoon, the period from June to September (also referred to as the summer monsoon) is generally enriched with large amount of precipitation over the Indian sub-continent. The period between March and May is termed as the pre-monsoon, while the period from October to November is referred to as the post-monsoon. Hence the coastal ABL characteristics over Thiruvananthapuram undergo prominent seasonal variations within a cycle of 1 year (Nair et al., 2011). Here we have classified the whole database consisting the model-simulated forecast fields and in situ observations into three broad categories – (i) clear-sky days, (ii) cloudy but non-precipitating days (hereafter referred to as the cloudy days) and (iii) rainy days. The classification is based on the diurnal variations in the incoming solar radiation, cloud fraction and rainfall. In the first class, the diurnal variation of the incoming solar radiation remains idealistic due to the absence of clouds. The in situ measurements of the incoming solar radiation through an AWS helped in choosing these days. A majority of days in this class are from the winter monsoon during which most of the days represent the clear-sky

conditions over Thiruvananthapuram. In the second category, the incoming solar radiation is attenuated due to overcast conditions. Prior to choosing these days, it was confirmed through the HRM model simulations that the experimental site is covered with a minimum of 50 % cloud fraction. In this category, it was also considered that the rainfall should not affect the diurnal variations in the fluxes; hence zero amount of rainfall in the in situ measurements and the model simulations is kept as another measure for the identification of cloudy days. A reasonable number of databases in this category are chosen from the pre-monsoon season during which the cloudy conditions prevail over Thiruvananthapuram. In the case of the third category, it was assured through the model simulations in conjunction with the AWS measurements that all the days chosen in this category are indeed affected with a minimum of 2 h of continuous precipitation. A minimum of 15 days of data are taken to represent each category, and the investigations are carried out for studying the importance of roughness length ratios in conjunction with the varying stability conditions in surface-layer parameterization scheme.

4 Results and discussion

4.1 Sensitivity of the z_{0m}/z_{0h} ratio

With a view to understanding the sensitivity of the z_{0m}/z_{0h} ratio in the determination of the heat exchange coefficient for varying meteorological conditions, we show the behaviour of C_H with respect to different magnitudes of Ri_B representing the unstable and stable stratification of the atmosphere respectively in Fig. 1a and b. Following the expressions of C_H described in Sect. 2, theoretical calculations are carried out for three different values of z_{0m}/z_{0h} ratio (= 1; 100; and 400 representing the L-79, L-100, and L-diurnal configuration of the HRM model simulations respectively). In these calculations, a constant value of about 0.42 m is assigned to z_{0m} for representing the momentum roughness length over Thiruvananthapuram following the GME (German global model) analyses fields. In the L-diurnal configuration, the peak value of $\ln\left\{\frac{z_{0m}}{z_{0h}}\right\}$ was set to a fixed value (= 6), roughly corresponding to $z_{0m}/z_{0h} \approx 400$ (see Table 1). These theoretical calculations yield high values of C_H for the unstable atmosphere and low values for the stable stratification. From Fig. 1a, it is seen that the magnitudes of C_H for unstable conditions of the atmosphere estimated through the L-79 configuration are extremely sensitive to the changes in Ri_B , where a slight variation from -0.2 to -10 in Ri_B leads to a drastic increase in C_H from $\sim 36 \times 10^{-3}$ to $\sim 240 \times 10^{-3}$. However, such sensitive changes are not evident for the L-100 and L-diurnal configurations, and the magnitudes of C_H are significantly lower than the corresponding values obtained through the L-79 approach (Fig. 1a). It may also be noted from the Fig. 1a that the magnitudes of C_H estimated through the L-79

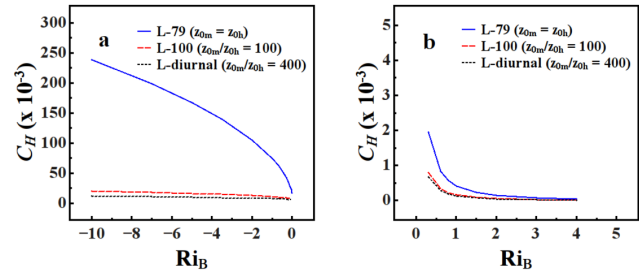


Figure 1. Sensitivity of the bulk transfer coefficient for heat (C_H) with respect to the bulk Richardson number (Ri_B) for (a) unstable and (b) stable conditions of the atmosphere.

approach for the unstable conditions are significantly higher than the corresponding magnitudes obtained through the L-100 and L-diurnal configurations. However, in the case of the stable atmosphere (Fig. 1b), we do not find any significant differences in the C_H values for three different configurations.

4.2 Evaluation of the L-79, L-100 and L-diurnal configurations for varying meteorological conditions

In Fig. 2a–c, the mean diurnal variations in H obtained through the HRM model simulations for the clear-sky, cloudy, and rainy days respectively are compared with the concurrent in situ observations. For the assessment of three configurations of the model simulations, the root-mean-square errors (RMSEs) with respect to the in situ measurements are estimated on an hourly basis and are shown in Fig. 2d–f. As three classes of the database are based on the sky conditions and the stability of the atmosphere, the mean magnitudes of H observed for the clear-sky, cloudy, and rainy days show distinct variations (Fig. 2a, b, c). During clear-sky conditions, a good amount of the incoming solar radiation reaching the earth's surface is transformed in the form of H ; hence the in situ observations corresponding to local noon indicate high values of H ($\approx 294 \text{ W m}^{-2}$, Fig. 2a). The peak magnitude of the H was $\approx 252 \text{ W m}^{-2}$ for the cloudy conditions and $\approx 163 \text{ W m}^{-2}$ only for the rainy days (Fig. 2b, c). In the case of model simulations with the L-79 configuration for the clear-sky conditions, the magnitudes of H were always higher than the corresponding in situ measurements, and the differences between the two were very significant during the daytime as the peak magnitude of H corresponding to the local noon was about $\approx 452 \text{ W m}^{-2}$ in the HRM model simulations, almost 158 W m^{-2} higher than the corresponding in situ observations. Similar features were seen in the case of cloudy conditions also, as the L-79 configuration yielded overestimated values of H in comparison with the in situ observations during the daytime, though the differences between the two were not very large (Fig. 2b, e). On the other hand, the HRM model simulations with the

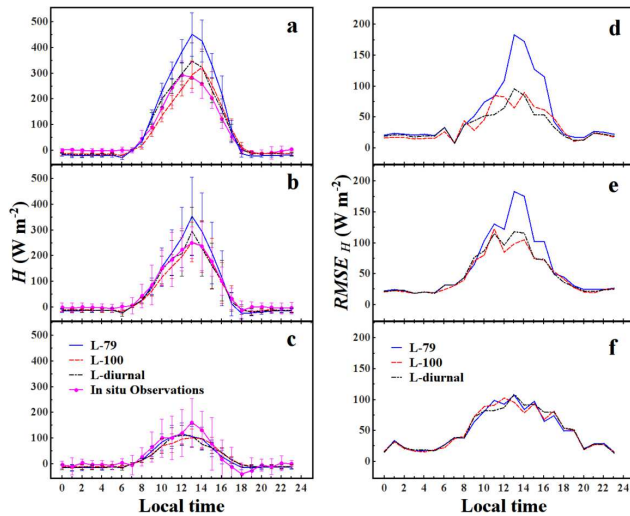


Figure 2. Left panel: comparison of the mean diurnal variations in H obtained through the L-79, L-100 and L-diurnal configurations together with the concurrent in situ observations for (a) clear-sky, (b) cloudy but non-precipitating, and (c) rainy days. Right panel: diurnal variations in the RMSE associated with the L-79, L-100 and L-diurnal configurations corresponding to (d) clear-sky, (e) cloudy but non-precipitating, and (f) rainy days. Vertical error bars represent the standard deviations in the corresponding measurements.

L-100 and L-diurnal configurations for the clear-sky as well as for the cloudy conditions were superior to the L-79 configuration as they reproduced the diurnal evolution of H in a more realistic way with relatively less errors. In the case of rainy days, all the three configurations of the surface-layer parameterization scheme yielded very similar variations in the H , and there were no significant differences in the diurnal variation of the RMSE associated with the model simulations (Fig. 2c, f). The prevailing meteorological conditions for rainy days are prone to highly stable stratification of the surface layer, and are therefore characterized by large positive values of the Ri_B . The H simulations are not significantly altered. From a forecasting point of view, such conditions are directly linked with the performance of convection parameterization scheme of the model, which often play a crucial role in the determination of stability class of the atmosphere. It may also be noted that the time of the observed maximum heat flux as seen in the in situ measurements is slightly different for the three different stability regimes, whereas such a difference is not prominent in any of the model simulations. Such differences are attributed to highly localized meteorological features which are generally confined to very small spatial domains and are not captured within the model grid resolutions.

As described in the Sect. 2, three different configurations of the surface-layer parameterization scheme are explicitly based on the differential treatment of the thermal roughness length. While the L-79 configuration assumes the roughness

lengths for momentum and heat in a uniform fashion, the other two configurations advocate for large values to the z_{0m}/z_{0h} ratio. It is a well-established fact that the differential treatment of thermal roughness length in the surface-layer parameterization scheme is a must, especially for the heterogeneous terrain (Garratt and Hicks, 1973; Garratt, 1992; Kot and Song, 1998; Anurose and Subrahmanyam, 2013). In the present study, the HRM model simulations with differential treatment of the z_{0m}/z_{0h} ratio did not show similar kinds of improvements for the prediction of H under varying meteorological conditions. In the case of clear-sky conditions, the improvements were very striking and significant, whereas there were no major differences in the model-simulated H for the L-79, L-100 and L-diurnal configurations corresponding to the rainy days. Therefore it is arguable that the performance of the surface-layer parameterization scheme in the HRM model simulations is reasonably affected by the varying meteorological conditions apart from the adequate treatment of the roughness lengths. For varying meteorological conditions under the clear-sky, cloudy and rainy days, the atmospheric stability is represented through Ri_B , which in turn is directly related with the magnitudes of H through the heat exchange coefficient. With a view to investigating the relative dominance of the atmospheric stability in the determination of H , taking the magnitudes of Ri_B as the prime indicator of the degree of stability, we have divided the entire database into two categories: (i) highly unstable atmosphere represented by $Ri_B < -1.0$, and (ii) near-neutral or stable atmosphere represented by $Ri_B \geq -1.0$. For restricting the analysis to the sunlit atmosphere with intense thermal convection, we have confined our database from 08:00 to 12:00 UTC. Figure 3a, b, and c show the percentage share of highly unstable and near-neutral or stable atmosphere for the clear-sky, cloudy, and rainy days respectively obtained through the model simulations. It is clear from these figures that the database representing the unstable atmospheric flow is dominant only in the case of clear-sky conditions. About 75 % of the clear-sky database falls under the highly unstable category with the magnitudes of $Ri_B < -1.0$ (Fig. 3a). It may be recalled from Fig. 1a that the heat exchange coefficients for this category are extremely sensitive to the magnitudes of Ri_B for the L-79 configuration and yield relatively higher values of C_H than the corresponding values obtained through the L-100 and L-diurnal configurations respectively. In the case of the L-100 and L-diurnal configuration for the clear-sky conditions, even though the magnitudes of Ri_B represent highly unstable atmosphere, the resulting magnitudes of C_H remain reasonably low (Fig. 1a), thereby producing the low values of H rather close to the real-world variations as seen in Fig. 2a. In contrast to this, merely 5 to 11 % of the database falls under the unstable category for the cloudy and rainy days (Fig. 3b, c). Thus, a majority of the data for cloudy (89 %) and rainy (94 %) days represent the near-neutral and stable atmospheric flow where the magnitudes of Ri_B are always larger than -1.0 . Since the magnitudes of C_H under

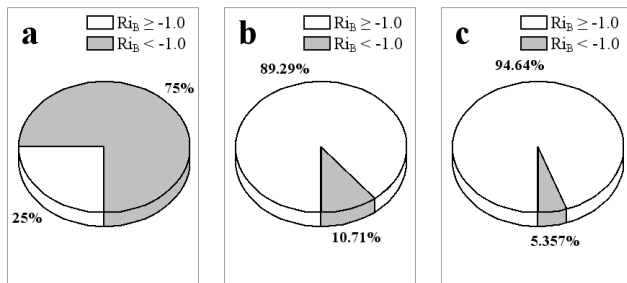


Figure 3. Percentage share of the unstable (represented by $Ri_B < -1.0$) and near-neutral or stable atmosphere ($Ri_B \geq -1.0$) database for (a) clear-sky, (b) cloudy but non-precipitating, and (c) rainy days.

the stable atmosphere did not show extreme variations for the positive values of Ri_B (see Fig. 1b), its immediate implications were clearly seen in the simulated variations of H for the cloudy and rainy days.

From the simulations of H through three different configurations of the surface-layer parameterization scheme in the HRM model for varying meteorological conditions, it is apparent that none of these configurations was able to reproduce the magnitudes of observed heat fluxes very perfectly during the local noon (Fig. 2a–f). The differences in the magnitudes of simulated and in situ measurements of H for the local noon can be attributed to the possible errors in the estimation of the heat exchange coefficient. The sensitivity analysis of the C_H with respect to the Ri_B provided quantitative evidence for the overestimation of H . By accounting the differential treatment of the z_{0m}/z_{0h} ratio in the L-100 and by subjecting this ratio to a diurnal variation in the L-diurnal configuration, the overestimated magnitudes of the H for the local noon were reasonably reduced, in turn justifying the need for such modifications to the L-79 configuration. For the stable atmosphere, the differential treatment of the roughness length did not yield significant changes in the magnitudes of simulated H over a diurnal cycle and is attributed to the suppressed magnitudes of the C_H for the positive values of Ri_B . Thus, it is clear from this piece of research work that the differential treatment of the roughness lengths, together with the atmospheric stability, drives the performance of a surface-layer parameterization scheme in the NWP models (Anurose and Subrahmanyam, 2013; Kot and Song, 1998).

5 Conclusions

In this research note, we assessed the performance of three different configurations of a surface-layer parameterization scheme based on Louis (1979) by comparing the model simulations with the concurrent in situ measurements of H over the experimental site of Thiruvananthapuram, India. Among the three configurations used in the present study, the L-100 and L-diurnal configurations were based on the differential

treatment of the roughness lengths, whereas the L-79 configuration assumed uniform treatment for the momentum and thermal roughness lengths. Based on the HRM model simulations of H for varying meteorological conditions, the main conclusions drawn from the study are as follows:

- Differential treatment of the roughness lengths in the Louis (1979) parameterization scheme tends to improve the predictability of H with better accuracy for the clear-sky and cloudy conditions. However, it does not alter the magnitudes of simulated H significantly for the rainy days. This research work shows the sensitivity of such a differential treatment for varying meteorological conditions.
- Model-simulated magnitudes of the H with the L-79 configuration for the local noon under clear-sky conditions are mostly larger than the corresponding in situ measurements. These differences are attributed to the sensitive behaviour of the heat exchange coefficients for the unstable atmosphere.
- Magnitudes of Ri_B for a majority of the cloudy as well as the rainy days were larger than -1.0 , in turn representing the near-neutral or stable stratification. Under these conditions, the estimated values of the C_H remained less variant, which were also reflected in the diurnal variations of H .
- Results from this study highlight the importance of atmospheric stability and differential treatment of the roughness lengths in the determination of H for varying meteorological conditions. They also quantified the sensitivity of the C_H with respect to Ri_B .
- However, a differential treatment of z_{0m} and z_{0h} in surface-layer parameterization scheme yield improved results in simulation of H . This article also emphasized the need for a fair representation of the stability conditions of the surface layer in atmospheric models.

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