Simulation of Diurnal Variation of Planetary Boundary Layer Parameters over Western Ghats of India

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1. Introduction:

A wide range of the atmospheric phenomena responsible for controlling the local weather conditions essentially have micro to mesoscale evolution. Even though these phenomena are greatly influenced by large-scale dynamics, they have direct and local interaction with mesoscale processes. These interactions are highly complex and their evolution in the free environment is determined by the underlying surface and its evolution. Topography is major factor which strongly modulates the exchange of energy and momentum between the surface and the overlaying atmosphere and is consequently responsible for spatial and temporal variability of the Planetary Boundary Layer (PBL) parameters such as mixing layer height, convective boundary layer height, and temperature lapse rates. The understanding of diurnal variations of these parameters is critical for prediction of the regional weather. To simulate their diurnal variation we have used Weather Research and Forecasting Model (WRF) developed by National Center for Atmospheric Research (NCAR), USA. The simulations using this model have been carried out for the period 11 – 19 April 2005 with the spatial extent of simulation domain as shown in Fig. 1. We have validated simulated surface temperatures for five synoptic meteorological stations of India Meteorological Department (IMD) viz. Mumbai (19^o 07' N, 72^o 51' E; 15 m), Goa (15^o 28' N, 73^o 54' E; 30 m), Cochin (9^o 57' N, 76^o 16' E; 3 m), Bangalore/ Bengaluru (12^o 58' N, 77^o 35' E, 920 m) and Pune (18^o 26' N, 73^o 55' E, 569 m), where the former four stations are RSRW observatories. Also, Mumbai, Goa and Cochin are located in the westward side of the Western Ghats separated by approximately 5^o latitudes and having low elevations. Pune and Bangalore are located on the eastward side (Fig 1) of Western Ghats and can be treated as hill stations. This study validates the simulated PBL structure by the WRF model over Western Ghats of India at these selected locations. The next section describes WRF model initialization and configuration while the results obtained from this work are discussed in section 3.

2. Model Initialization and Configuration:

WRF is a next generation, fully compressible, Euler non-hydrostatic mesoscale forecast model with a run-time hydrostatic option. The detailed description of WRF is presented in Wang et. al.(2004) and Skamarock et al (2005). For this study, two way nested computational domains of 70 X 105 X 40 and 85 X 197 X 40 grid points and horizontal resolutions of 32 km and 8 km respectively have been chosen (Fig. 1). The first domain covers most of the Indian subcontinent, ranging from 0 – 30^o N in latitude and 65 – 85^o E in longitude. The second domain covers the Western Ghats region of southern peninsular India ranging from 8 – 22^o N in latitude and 72 – 78^o E in longitude. The model is initialized by real boundary conditions using NCAR-NCEP's Final Analysis (FNL) data (NCEP-DSS1, 2005) having a resolution of 1^0 x 1^0 (~ 111 km x 111 km). The model is integrated for the period 11 – 19 April 2005 using a time step of 180 seconds. Other model configuration details are provided in table below.

Parameterization	Selected Scheme
PBL	Yonsei University (Hong et al, 2006; Hong and Dudhia 2003)
Surface Clay	Similarity theory (Paulson 1970; Dyer and Hicks 1970; Webb 1970)
Surface Physics	Noah (Chen and Dudhia, 2001)
Microphysics	Lin et al. (1983)
Cumulus Physics	BMJ (Janjic, 2000)
Long wave Radiation	RRTM (Mlawer et al., 1997)
Short wave Radiation	Dudhia (1989)

3. Results and Discussions:

Fig. 2 (a) shows the mean deviation of simulated surface temperatures using WRF model from observations recorded by IMD (NCEP-DSS2, 2005). It is seen that the deviation lies within ± 2^o C. The maximum positive departure is observed at Bengaluru at 1400 hrs UTC and the highest negative at Mumbai during the same time. It can be seen that Cochin, Goa and Pune show relatively less departure from observations. It is observed that the simulated surface temperatures follow similar diurnal trends with correlations of 92, 90.98, 92.38, 94.34 and 90.56 for Mumbai, Goa, Cochin, Bengaluru and Pune respectively. The standard deviations of simulated temperature are 4.05, 2.65, 2.24, 3.2, and 4.42 for Mumbai, Goa, Cochin, Bengaluru and Pune respectively. The positive (negative) temperature deviations can affect the values of PBL parameters, caused by an increase (decrease) in the Monin-Obukhov length (L), which in turn decreases (increases) the surface friction velocity (u*) and convective velocity scale (w*). However, the effect of this deviation on u* and w* is not expected to be significant as u* varies inversely with the logarithm of L^{-1} (Panofsky and Dutton, 1984) and w* varies with the cube root of temperature (Deardorff, 1970). The anomaly in the predicted temperature affects estimates of surface heat flux (HFX) and therefore the height of convective (CBL) and mechanical (Zm) boundary layer. Fig. 2 (b-d) shows the simulated HFX, CBL and Zm respectively. As seen from the figures, these parameters show similar behavior to that of surface temperatures. The magnitude of HFX ranges between 70 to 370 Wm^{-2} with minimum at Cochin and maximum at Mumbai. The values of peak CBL (Zm) range from 1000 (100) to 3500 (1000) meters with the above locations for maximum and minimum. The simulated CBL and Zm extend up heights of 3 Km and 1 Km respectively and show a reduction with decrease in the latitude. The ratio of latitudinal decrease in magnitude of these parameters from Cochin to Goa and Goa to Mumbai ranges between 2 to 3. Same is seen for Pune and Bengaluru. Even though Cochin, Goa and Mumbai are separated by about 5^o, the PBL parameters show more variability between the Goa to Mumbai than Cochin to Goa. This may be attributed to the march of the Sun from lower latitude towards Tropic of Cancer during this season.

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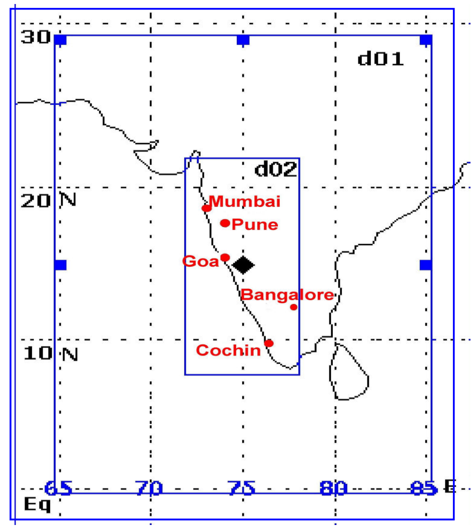

Fig –1: Domain for WRF simulation

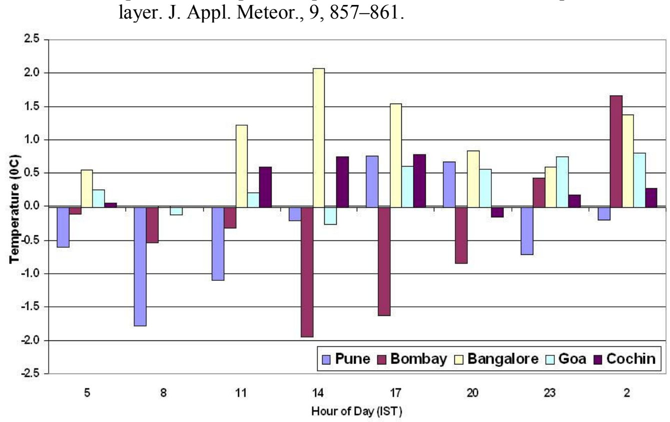

Fig-2(a): Mean Deviation of Surface Temperature from Observed

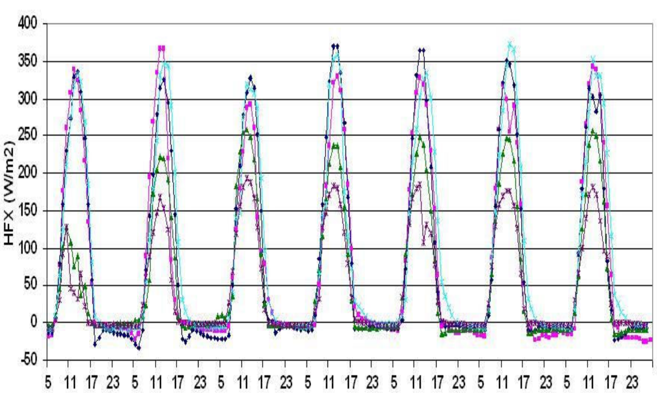

Fig- 2 (b): Surface Heat Flux

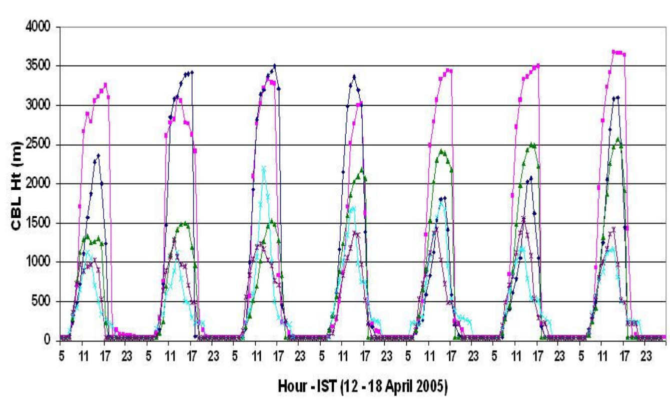

Fig-2 (c) Convective Boundary Layer Height

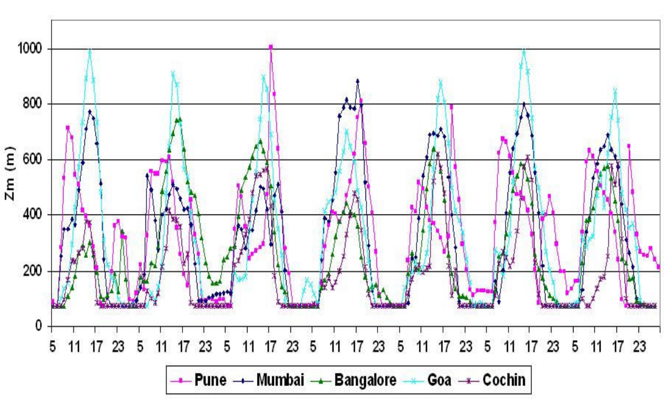

Fig-2 (d) Mechanical Mixing Layer Height