Impact of Spatial Resolution on Meteorological Parameters using WRF Model over Jaipur, India

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***Abstract*—Model resolution plays an important role in numerical modeling. A coarse model resolution outputs (i.e. temperature, relative humidity, wind direction etc.) may differ a large from real-time observations. In this paper, a performance evaluation study using Weather Research and Forecasting (WRF) model has been carried out over Jaipur (26.9 N, 75.8 E), a semi arid region in India. The study focus is to determine efficiency of the model over a chosen grid domain centered on Jaipur region using different spatial model resolutions. The model was run using the best physical parameterization scheme with different spatial model resolutions. The performance of the model varies with the different combination of the model resolution. The model simulations show encouraging and better statistical results for 24 km model resolution considering the balance between total computation time and model performance on the same computer configuration.**

Keywords—Numerical model, WRF, resolution, paramterization.

1. INTRODUCTION

In the present study, we have used the Weather Research and Forecasting (WRF) model version 3.3.1 to simulate the surface meteorological observations over Jaipur (26.9 N, 75.8 E), Northwestern India and examined its sensitivity with the varying horizontal model resolution using the best parameterization scheme as suggested by Soni et al., 2014 [1] over the same region. Air temperature (T), relative humidity (RH) and wind speed (WS) are key variables for every meteorological phenomenon. These variables are studied to understand the atmospheric variability and trends. Selection of particular spatial resolution in the numerical model is an important step in understanding the local weather characteristics of a region for its topography. Also model's horizontal resolution is important to understand the optimum resolution for dynamic downscaling [2]. The impact of different spatial resolution is presented in section 2 in details.

2. METHODOLOGY

2.1 Model Configuration

The study uses the WRF mesoscale model with capability to run with and without nesting. The model is developed primarily at the National Center for Atmospheric Research (NCAR) in collaboration with different agencies like the National Oceanic and Atmospheric Administration (NOAA), the National Center for Environmental Prediction (NCEP), and many others. The WRF is a limited-area, non-hydrostatic, primitive-equation model with multiple options for various physical parameterization schemes [3]. The model follows terrain and conserves the scalar variables [4].

Different physics options are available in the model that can be used as per need. It is essential to run different simulation schemes to find out the better combination for a particular location. The physical parameterization options available in the model are 1) Microphysics 2) Surface Layer Parameterization 3) Land Surface Parameterization 4) Planetary Boundary Layer Parameterization 5) Cumulus Parameterization and different radiation schemes for boundary layer land process. [Available on-line at http://www.mmm.ucar.edu/wrf/users/docs/arw_v3.pdf]

In present study, default configuration of WRF model is utilized in all experimental set up following the best combination of physical parameterization scheme as suggested by Soni et al., 2014 [1] which showed better statistical results when the microphysics scheme, Lin et al.,1983 [5] was chosen over the study region. Surface and planetary boundary scheme is Quasi-Normal Scale Elimination (QNSE) which is generally used for stably stratified regions. The land surface model scheme is NOAH land-surface model which contains soil and moisture in four layers and also accounts for frozen soil and multi layer snow. The cumulus parameterization scheme is Kain-Fritsch, a new Eta scheme which is generally used for sub tropical regions having less large scale forcing. The short wave and long wave radiation scheme chosen for that simulation was Dudhia which is suitable for clouds, clear sky absorption and scattering and RRTM (Rapid Radiative Transfer Model) which is suitable for multiple bands, trace gases and microphysics species. So keeping this in view, same physical parameterization was chosen for varying model resolutions.

2.2 Design of Experiments

The initial and lateral boundary conditions are same for all experiments which are taken from NCEP Reanalysis FNL dataset 1°×1° every 6 hours. The model integration is carried out for 72 hours with integration every 1 hour over the selected domain (23°N-31°N, 72°E-80°E) shown in Fig. 1. The projection chosen for the whole experiment is Mercator projection and non-hydrostatic dynamics has chosen for simulation.

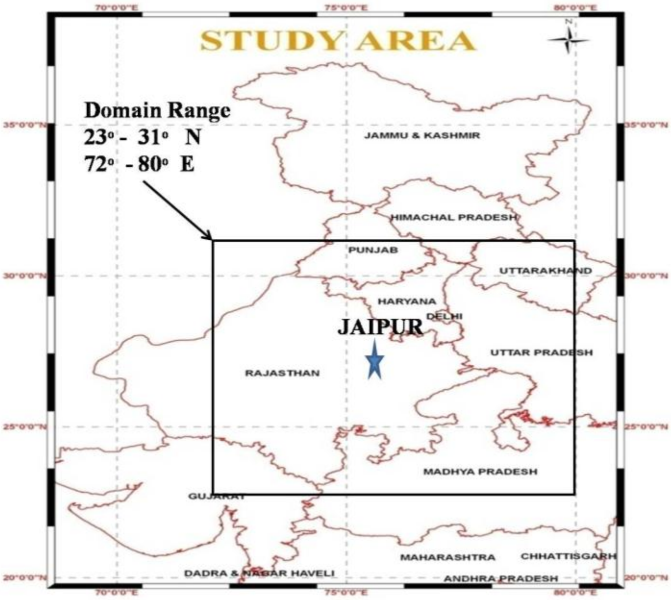

Fig. 1 : The study area

2.2.1 Simulation Period

The simulations are carried out for a week from January 8 to January 14, 2012. During 11--14 January, 2012, wunderground (http://www.wunderground.com) observations over Jaipur station shows the absolute minimum for the winter season during 2011-2012. A detailed analysis of the model simulated results are carried out for above period with a special emphasis from the 00:00 UTC, January 11 to 00:00 UTC January 14, 2012, as it was the coldest period of the year 2012.

We have obtained the surface observations from the Wunderground (http://www.wunderground.com/) for Jaipur station and considered as verification data to validate the model results at station level. This website collects weather information directly from weather stations all round the globe. These weather stations are owned by several government agencies and sometimes international airports. In Jaipur, there is weather station located at Sanganer Airport (26.82 °N, 75.81 °E). The surface variables namely temperature, pressure, relative humidity, wind speed and direction are available at an interval of 30-60 minutes. We have taken every 1 hour data for comparison with model simulated outputs.

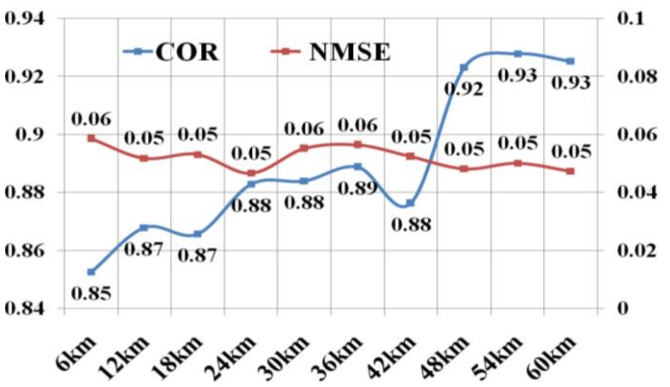

Fig. 2.2 Relative Humidity

Figure 2.1 and 2.2 shows the correlation and NMSE graph for temperature (T) and Relative Humidity (RH). For T, model resolution of 24km and 48km performed better. For RH, 54km and 60km perform better than other model resolutions.

Results of detailed statistical analysis are presented in Tables 2, 3, and 4 for T, RH and WS respectively. An ideal model output must have minimum value of NMSE (≈0) with maximum value of COR (≈1), FB close to 0 (positive or negative) and FA2 which is in percentage close to 100.

TABLE 2. Temperature Statistics 11 January 2012 -14 JANUARY, 2012

	TEMPERATURE STATISTICS			
	NMSE	COR	FB	FA2
6KM	0.03	0.95	0.10	100.00
24KM	0.03	0.96	0.12	100.00
18KM	0.03	0.94	0.11	100.00
12KM	0.03	0.95	0.12	100.00
30KM	0.04	0.95	0.14	97.06
36KM	0.04	0.94	0.16	100.00
42KM	0.05	0.94	0.17	100.00
48KM	0.06	0.96	0.19	85.71
54KM	0.07	0.96	0.22	82.86
60KM	0.07	0.96	0.22	82.86

Tables have been sorted in ascending order for NMSE and FB, descending order for COR and FA2. On the basis of statistical analysis it is seen that 24 and 6km resolution works better for temperature; 24 and 60 km for relative humidity; and 42km and 18km for wind speed than other considered model resolutions.

Fig. 3 shows the observed Vs 6km and 24 km simulation output for temperature and relative humidity. We see from the figure that for temperature 6km was able to produce better output (close to observations) than 24km but for relative humidity 24km performed better then 6km.

TABLE 3. Relative Humidity Statistics 11 January 2012 -14 JANUARY, 2012

	RELATIVE HUMIDITY STATISTICS			
	NMSE	COR	FB	FA2
24KM	0.05	0.88	-0.07	97.14
60KM	0.05	0.93	-0.15	97.14
48KM	0.05	0.92	-0.15	97.14
54KM	0.05	0.93	-0.16	97.14
12KM	0.05	0.87	-0.01	94.29
42KM	0.05	0.88	-0.10	94.29
18KM	0.05	0.87	0.00	94.29
30KM	0.06	0.88	-0.12	94.12
36KM	0.06	0.89	-0.14	94.29
6KM	0.06	0.85	0.00	94.29

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TABLE 4. Wind Speed Statistics 11 January 2012 -14 JANUARY, 2012

	WIND SPEED STATISTICS			
	NMSE	COR	FB	FA2
42KM	1.82	0.33	-0.86	28.57
18KM	2.00	0.35	-0.96	26.47
12KM	2.19	0.23	-0.95	25.71
36KM	2.21	-0.12	-0.76	25.71
24KM	2.28	-0.01	-0.88	28.57
6KM	2.28	0.17	-0.99	25.71
48KM	2.29	-0.05	-0.80	25.71
54KM	2.40	-0.15	-0.81	28.57
60KM	2.41	-0.23	-0.79	25.71
30KM	2.65	-0.41	-0.73	20.59

Observations show overall wind direction is blowing from South to North direction. Both 6km and 24km was able to simulate the observe wind direction but not magnitude i.e. wind speed.

Overall, 24km performed better than 6km when correlation, NMSE, FA2 and FB are considered. 24km model resolution performed better statistical results then other spatial resolution.

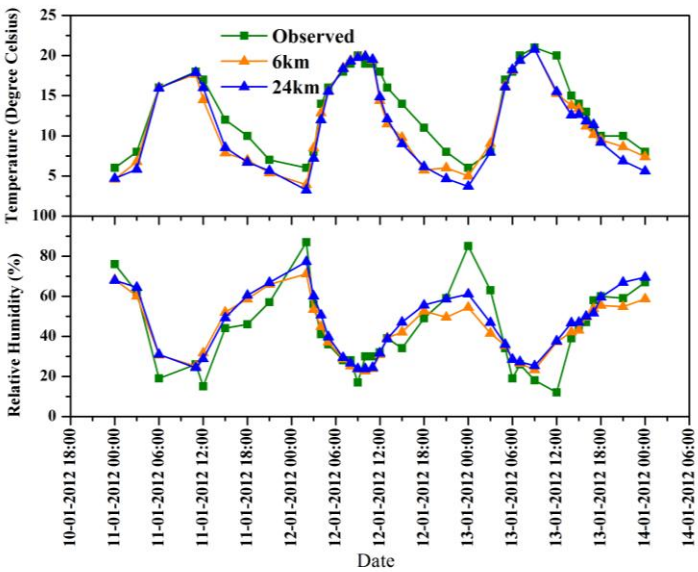

Fig. 3.Observed Vs Simulated Temperature and RH for 11-14 January, 2012

3. CONCLUSIONS

The present study explores the sensitivity of different model resolutions to meteorological variables. To examine the sensitivity of the model resolutions, ten different model resolutions were considered using the similar initial and lateral boundary conditions from the NCEP/NCAR reanalysis.

In general, the WRF model is found to reproduce the observed variations in meteorological variables well in all of the experiments consistently. The results depicts that 24km spatial resolution gives better statistical results and also produces the smallest biases over the study area which is critical for regional simulations.

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