DOWNSCALING OF WRF MODEL FOR IMPROVED CHARACTERISATION OF SEVERE DUST STORM

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Abstract: Severe local convective storm is the most crucial weather event over the Indian subcontinent, because of its dynamic nature. It is a mesoscale meteorological phenomenon. It occurs over the Indian region during pre monsoon season i.e. mid March to mid June. This convective phenomenon is associated with dust storm, thunderstorm, lightning, hailstorm, squall line and tornado. This dynamical nature of SLCS is hazardous for lives and properties. The mechanism of SLCS produces a dust storm if sufficient moisture content is not present at the lower level of the atmosphere. This paper presents a case study of severe dust storm that occurred over NCR Delhi and neighboring region between 1630 hrs IST and 1730 hrs IST of 30th May 2014. Weather Research and Forecasting (WRF) model version 3.6.1 is used to numerically simulate and investigate the above said severe dust storm. Sensitivity experiments are conducted to study the impact of different domain resolution (9km and 1km) with the similar microphysics (MPs) scheme for the simulation of the event. The paper demonstrates that better structure and intensity of the dust storm are simulated by downscaling of WRF model

Keywords- Numerical simulation; Dust storm; Weather Research and Forecasting model; Domain resolution.

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I. INTRODUCTION

The convective dust storms, which are also locally named as “Andhi”, take place in northwest region of India from mid March to mid June. During this season, comparatively low moisture, high vertical wing shear and temperature variation of lowest atmosphere stratum (low cloud) create favorable conditions for dust storm/thunderstorm to have high bases of the order of 3 to 4 km (Science Plan 2005) over the surface of the earth.

On the surface of earth, the land becomes dry and plenty of fine dust is available due to lack of water for a long time. During the rain, part of the water does not reach to the ground due to evaporation. The northwest India produces dust storm or Andhi (Joseph et al. 1980) due to low humidity in air near the surface of the earth. The earlier studies of Andhi, reveal that the wind speeds, humidity, pressures and temperatures are measured using instruments such as transmission meters, weather radar measurements. The radar measurements show that, a distance as large as 30 km has Andhi wall dust on the surface and associated cumulonimbus cloud. It is recorded (Joseph et al. 1980) that during these severe dust storms the horizontal visibility lowers down to less than 100 meters

II. SCOPE OF THE STUDY

The northern part of the Indian region is reported to have experienced every year, a large numbers of severe dust storm/thunderstorm, in the pre-monsoon season i.e. mid March to mid June. The uncertainty and risk due to severe dust storm invoked the researchers to study the nature of these events in the atmosphere in terms of time, location and intensity (fig 1.1). Therefore, it is a needed to conduct study and explore the information about the severity and location, intensity and time of occurrence of the dust storm. It is recognized to improve the prediction of this

important weather phenomenon. A numerical simulation of the severe dust storm makes it feasible to predict the better structure and intensity of the upcoming hazard and consequently occurring disaster so that an early warning can be issued to the people and preventive measures can be taken.

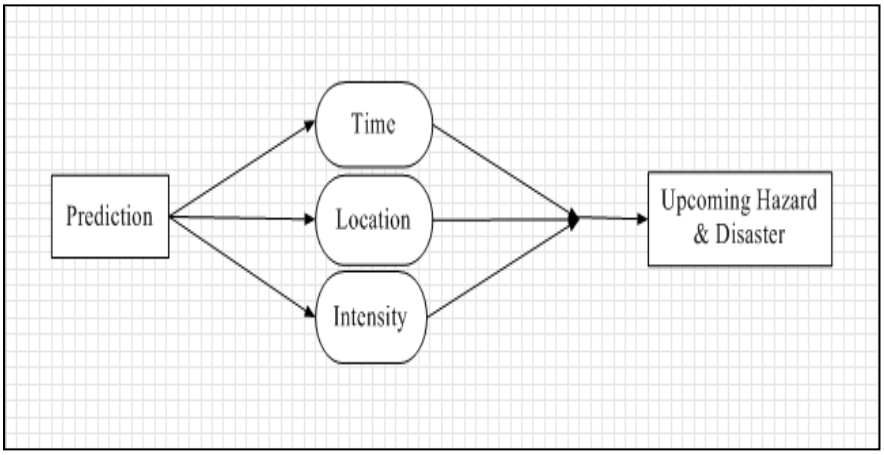

Figure (1.1): Scope of the study (Source: Jaya et al. 2015)

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III. DESCRIPTION AND PROGRAM FLOW OF MODEL

Model Description- WRF model (Version 3.6.1) with the Advanced Research WRF (ARW) is used to numerically simulate the severe dust storm. It is a multi-organization model which is used for both the purpose atmospheric research as well as operational forecast system. It is also convey the advance research into operations. The program flow of the WRF model is given in (fig 1.2).

Model Initial and Boundary Conditions- Sensitivity experimental study has been carried out on the Aaditya HPC system which is 790 + Teraflops High Performance Computing System (HPCS) IBM iData Plex cluster, which features 38,144 Intel Sandy Bridge processors and 149 TB of memory. The initial and boundary conditions are 29-05-2014 of 00 UTC and 31-05-2014 of 00 UTC has been used for numerical simulation and investigation of this event. By downscaling technique WRF model has been used to make 48 hours simulation of the event using different domain resolutions i.e. 9 and 1 km.

Program Flow of Model- Provides the details of the structure of WRF model and two different experimental domains (fig 1.3 & 1.4).

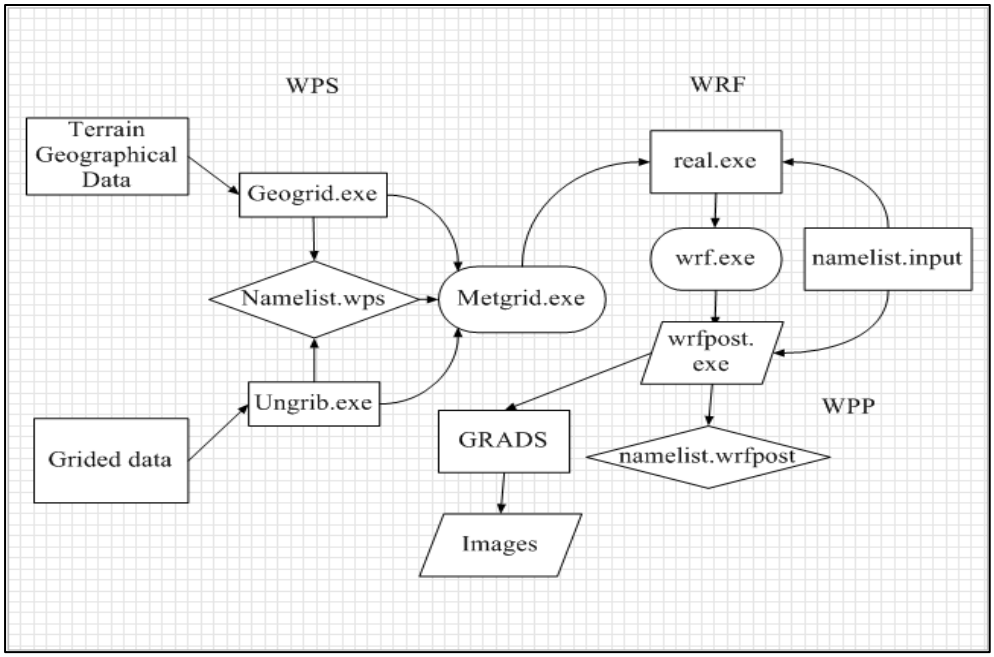

Figure (1.2): Program flow of WRF model (Source: Jaya et al. 2015)

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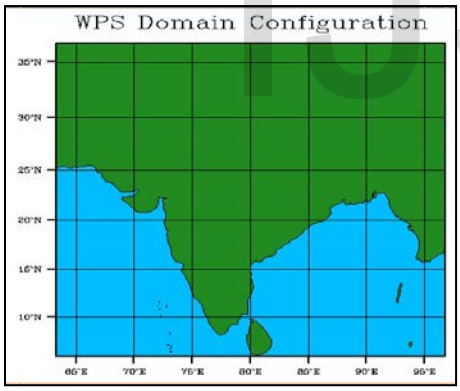
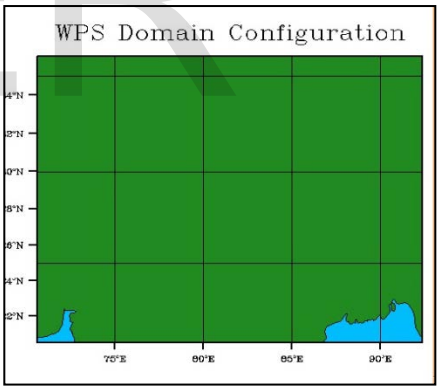


Figure(1.3): Experimental Domain 9 km resolution.



Figure(1.4): Experimental Domain 1 km resolution.

IV. RESULTS AND DISCUSSIONS

Sensitivity Experiments

The WRF V-3.6.1 model has been run for 48 hours to simulate the severe dust storm. The output is post processed to obtain geo-potential (500hPa), wind vector (500hPa), wind speed (10m). These numerical simulated results were obtained at different domain resolutions (9 and 1km) with the same microphysics (MPs) schemes. The USGS

terrain/vegetation data was used corresponding to the domain resolutions at 9 km and 1 km. Grid Analysis and Display System (GrADS) has been used for plotting the variables and discussed are as follows.

(i) Geo-potential and Wind vector

Fig (1.5 & 1.6) illustrate the simulated geo-potential and wind vectors at 500 hPa, valid at 12 UTC of 30 May 2014 based on the initial condition of 00 UTC of 29 May 2014 at domain resolutions of 9 km and 1 km respectively. The results indicate predominately north westerly winds over Delhi and neighborhood. The simulation at 1 km indicate a convergence zone which is extending from north to south over east Rajasthan and West U.P in the fig(1.6).

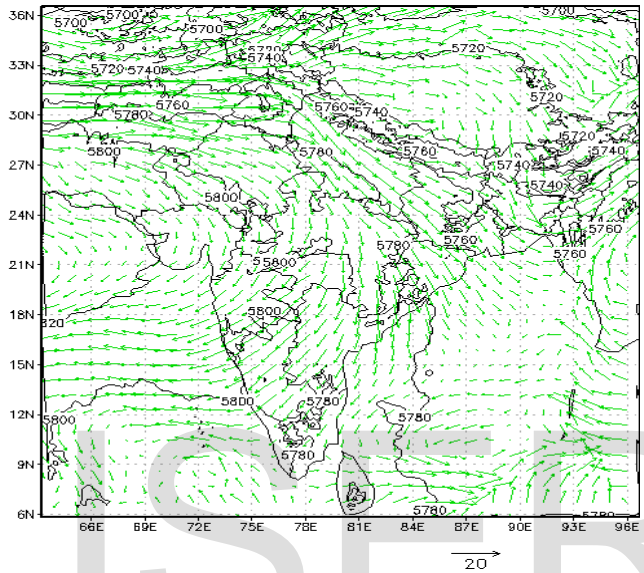


Figure (1.5): Simulated Geopotential and Wind vector at 500 hPa valid at 12 UTC, 30052014 based on the IC: 00 UTC, 29052014 at 9 km resolution.

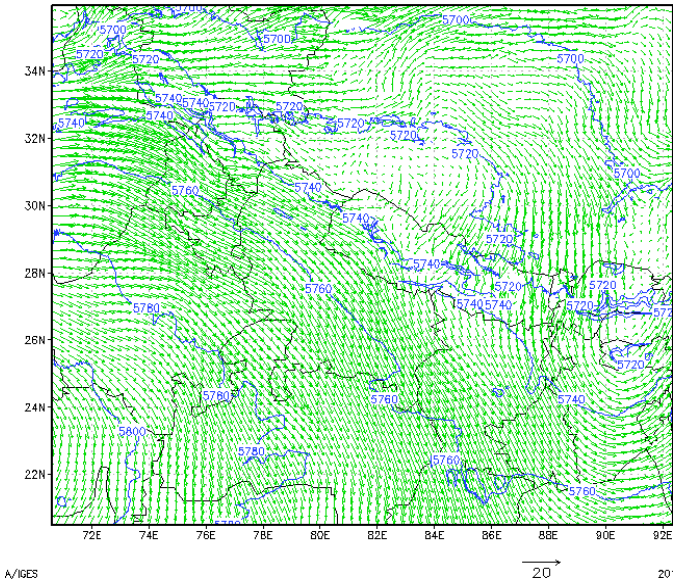


Figure (1.6): As in fig (1.5) but at 1 km resolution.

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(ii) Wind vector and Wind speed

Fig (1.7 & 1.8) illustrate wind vector at 850 hPa and wind speed at 10 m valid at 00 UTC of 30 May 2014 based on the initial condition of 00 UTC of 29 May 2014, at domain resolution of 9 and 1 km respectively. The results indicate flow of high wind speed over Delhi and neighboring regions in 1 km resolution which is not seen in 9 km resolution. The shaded values indicate isotach. Thus the simulation at downscaling of mesoscale (WRF) model is closer to the reality.

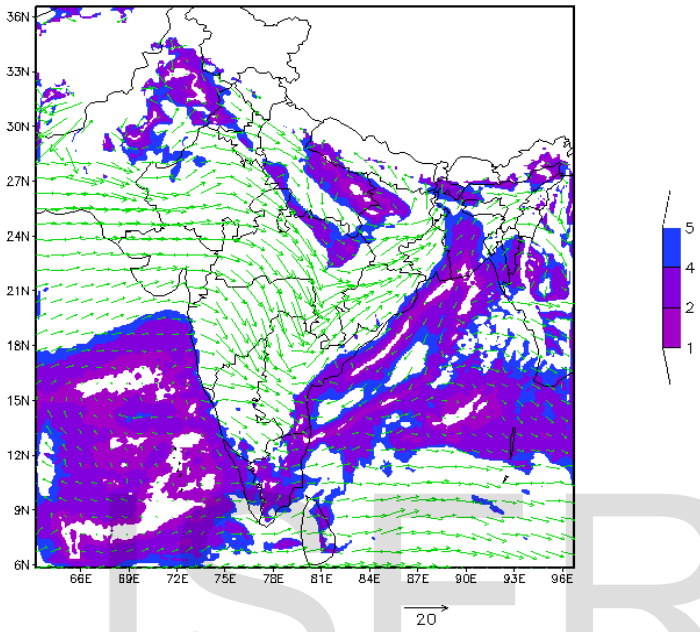

Figure (1.7): Simulated Wind vector at 850 hPa and Wind speed at 10 m valid at 00 UTC, 30052014 based on the IC: 00 UTC, 29052014 at 9 km resolution.

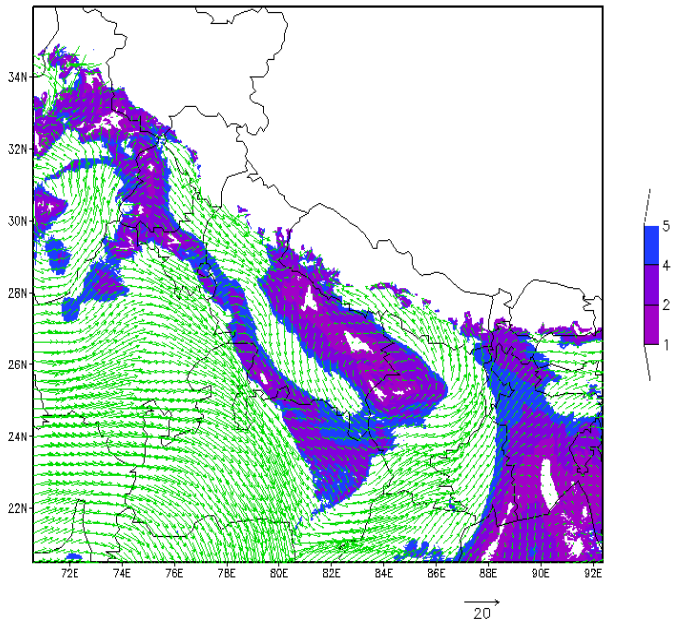

Figure (1.8): As in fig (1.7) but at 1 km resolution

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V. CONCLUSION

WRF V3.6.1 has been used to simulate and investigate a severe dust storm which affected NCR Delhi and surrounding regions between 1630 hours IST and 1730 hours IST of 30 May 2014. That system started from north western part of the India and moved eastward. It actively moved by a westerly trough. It was influenced by strong vertical extension of wind shear causing huge damage to the life and property. Results investigate that by downscaling of mesoscale WRF model simulates better structure and intensity of the system. By comparison of different domain resolutions (9 and 1 km) it can be seen that higher resolution at 1 km provides better distributions of convergence zone with respect to wind flow at lower level. However there are many limitations in the simulated results in terms of maximum wind speed observed at the surface, precise time and location of the dust storm. More sensitivity experiments need to be conducted for better forecasting of the event.

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