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Simulation of High-Altitude Meteorological Data Used to Environment Impact Assessment by MM5 Model

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Abstract

The high-altitude meteorological data on the 27km resolution, with 149× 149 grids in the whole country, are generated by application of mesoscale numerical model MM5. The raw data used by the model include the United States USGS data, including terrain, land use, the composition of the vegetation data, and so on. Original meteorological data are the reanalysis data of the US National Centers for Environmental Prediction of the NCEP/NCAR. According to the need of environment impact assessment (EIA), the high-altitude meteorological data contain 21 layers below 550 hPa height. The data mainly include atmospheric pressure, altitude, dry bulb temperature, dew point temperature, wind direction, wind speed, relative humidity. High-altitude meteorological data generated in this study, can be directly applied to the EIA prediction model and serve for EIA.

Key words: MM5; Mesoscale; High-altitude meterological data; Models

1. Introduction

Mesoscale meteorology which developed rapidly has become an important research field with great development potential and application prospect in modern meteorology science[1-2]. With the development of computer science, a large number of mesoscale numerical models have been used to simulate and predict atmospheric movement and meteorology changes [3-5]. MM5 model (the fifth generation NCAR / Penn State Mesoscale Model) has been widely used for tropical storms and other important mesoscale weather process simulation, and environmental science research [5-8]. High-altitude meteorological data is required when some EIA prediction models are used. The requirement was proposed by "Technical Guidelines for Environmental Impact Assessment of Atmospheric Environment" [9] launched in 2009. At present, the existing high-altitude meteorological stations in China can not cover the whole country. In order to meet the requirement of EIA atmosphere prediction needs, the nationwide high-altitude meteorological data for EIA services were generated by MM5 model simulation in this study.

2. The basic equations of MM5 model

MM5 is grid difference model based on multi-nested grid with the vertical coordinates by σ, and the horizontal using Arakawa B-grid coordinates. The vertical and horizontal resolutions can be adjusted according to specific applications [10].

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2.1 Pressure equation

$$\frac{\partial p'}{\partial t} - \rho_0 g w + \gamma p \nabla \cdot V = -V \cdot \nabla p' + \frac{\gamma p}{T}\left(\frac{\dot{Q}}{c_p} + \frac{T_0}{\theta_0} D_\theta\right)$$

2.2 Kinetic equation

$$\frac{\partial u}{\partial t} + \frac{m}{\rho}\left(\frac{\partial p'}{\partial x} - \frac{\sigma}{p^*}\frac{\partial p^*}{\partial x}\frac{\partial p'}{\partial \sigma}\right) = -V \cdot \nabla u + v\left(f + u\frac{\partial m}{\partial y} - v\frac{\partial m}{\partial x}\right) - ew\cos\alpha - \frac{uw}{R} + D_u$$

$$\frac{\partial v}{\partial t} + \frac{m}{\rho}\left(\frac{\partial p'}{\partial y} - \frac{\sigma}{p^*}\frac{\partial p^*}{\partial y}\frac{\partial p'}{\partial \sigma}\right) = -V \cdot \nabla v + u\left(f + u\frac{\partial m}{\partial y} - v\frac{\partial m}{\partial x}\right) + ew\sin\alpha - \frac{vw}{R} + D_v$$

$$\frac{\partial w}{\partial t} - \frac{\rho_0 g}{\rho p^*}\frac{\partial p'}{\partial \sigma} + \frac{gp'}{\gamma p} = -V \cdot \nabla w + g\frac{\rho_0 T'}{p T_0} - \frac{gR_d p'}{c_p\ p} + e(u\cos\alpha - v\sin\alpha) + \frac{u^2 + v^2}{R} + D_w$$

2.3 Thermodynamic equation

$$\frac{\partial T}{\partial t} = -V \cdot \nabla T + \frac{1}{\rho c_p}\left(\frac{\partial p'}{\partial t} + V \cdot \nabla p' - \rho_0 g w\right) + \frac{\dot{Q}}{c_p} + \frac{T_0}{\theta_0} D_\theta$$

3. MM5 model setup and data source selection

MM5 model initial field was made use of reanalysis data from the U.S. National Centers for Environmental Prediction, horizontal resolution of 1 ° × 1 °, a day of 4 times (00:00,06:00,12:00,18:00), using Lambert projection coordinate system, two true latitude lines (model for revised true latitude line) ,which were 25 ° N and 47 ° N. In this study, the coordinates of the center of the simulation region were 36 ° N, 105 ° E; the resolution was 27km. The number of grid points in horizontal direction was 22201(149 × 149), covering most of China's land area. Topography and surface types of data were made use of the U.S. Geological Survey (USGS) global data, topographic data using a global 30 second resolution terrain data, USGS data with 25 classes of surface types. Model was divided into 30 vertical layers δ, respectively 0.000,0.99,0.98,0.97,0.96,0.95,0.94,0.92,0.90,0.88,0.85, 0.82,0.79,0.76, 0.73,0.69,0.65,0.60,0.55 , 0.50,0.45,0.40,0.35,0.30,0.25,0.20,0.15,0.10,0.05,0.00. The top pressure was 100hPa. The output variables of model included ground variables and high altitude variables. Ground variables included surface pressure, temperature, wind, terrain height, latitude, longitude and so on. High altitude variables included the horizontal and vertical wind, temperature, water vapor mixing ratio and high altitude, etc. Model-generated data included 24 times one day.

The main physical processes were used by MM5 model, including Grell cumulus parameter scheme, MEF planetary boundary layer scheme, and simple ice explicit moisture scheme.

4. MM5 model composition and function to achieve

Four modules of MM5 model were applied in the process of this study. They were TERRAIN, REGRID, INETERPF, and MM5. Physical characteristics, the independent horizontal structure, and the distinct vertical stratification characteristic of atmosphere, make for a better calculation of atmospheric modeling of concurrent parallel computing features and greatly improved efficiency [11]. The simulated high-altitude meteorological data were generated by the application of 20 compute nodes with high-performance parallel computer at the same time, greatly improving the speed. TERRAIN module mainly performs two tasks: One is to establish the mesoscale regional grid; the other is to generate terrain files for the mesoscale regional, which is firstly used by REGRID module, and then used by MM5 module. TERRAIN is the first program of MM5 model system; each complete simulation starts from the program. Elevation and vegetation composition which were regulay distributed along latitude and longitude were horizontally interpolated (analyzed) to the selected mesoscale area by the TERRAIN module.

REGRID module's role is to read the pressure level data on weather analysis; and the analysis of data is interpolated from the original grid and map projection to the grid and map projection defined by the TERRAIN. REGRID is used to deal with isobaric surface and surface analysis data; and two-dimensional interpolation is executed in these layers. REGRID is the second step of the MM5 system flowchart, the need for the output from the

TERRAIN as its input, and the preparation of input files for the INTERPF. REGRID is a set of procedures to handle various tasks. These tasks are split into two parts: one is data input (such as reading the original analysis of meteorological data) by "pregrid" handle assembly; the other is interpolating to the MM5 grid point by "regridder" procedure.

INTERPF module is used to handle data conversion from the analysis pressure coordinates to Sigma coordinates, mainly including vertical interpolation, diagnostic analysis and reassigning data format. INTERPF obtain REGRID output data for input to generate initial and lateral boundary conditions and lower boundary conditions for the model.

MM5 module is the part of numerical weather prediction in the whole model system. MM5 can be used to study the theory and real-time applications such as forecast simulation on the monsoon, the hurricane and tornado; and it also can be used to four dimensional data assimilation. In the smaller of the β and γ scale (2-200km), MM5 can be used to study mesoscale convective systems, fronts, sea breeze, valley circulation, stream and urban heat island effect. In this study, the main application was the simulation of high-altitude meteorological data. During the calculation process of this module, 20 nodes in parallel computing were used.

5. Extraction of high-altitude meteorological data

Data generated by application of MM5 model was the unformatted of data. In order to make data directly applied to the EIA forecast model and served to EIA, we firstly needed to read the unformatted data by READV3 program. READV3 is a program of MM5 models, which function is to read the data generated by MM5. Then we wrote program on high-altitude weather data format conversion by the fortran language. Through the program running, we could convert the data read out by the MM5 readv3 to text format data for EIA. According to the EIA needs, we extracted high-altitude meteorological data which were total 21 layers and below 550 hPa height. The data mainly included atmospheric pressure, altitude, dry bulb temperature, dew point temperature, wind direction, wind speed, relative humidity. Moreover, by the program according latitude and longitude information, we could extract high-altitude meteorological data of any one place in the country.

6. Conclusions

The high-altitude meteorological data on the national 27km resolution, 149× 149 grids is generated by application of mesoscale numerical model MM5. The raw data used by the model from the United States USGS data, include terrain, land use, land-water signs, and the composition of the vegetation data. Original meteorological data come from the reanalysis of the data of the US National Centers for Environmental Prediction of the NCEP/NCAR. By application READV3 program and format conversion program of high-altitude meteorological data written by fortran language, the unformatted data generated from MM5 models is converted to text format data which is required by EIA. According to the EIA needs, the extracted data is 21 layers of weather data below 550 hPa height. The data mainly include atmospheric pressure, altitude, dry bulb temperature, dew point temperature, wind direction, wind speed, relative humidity. High-altitude weather data extracted by the research, can be directly applied to the EIA prediction model and served for EIA.

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References

[1] Bai J., Deng W., Cui B., Ouyang H. Water diffusion coefficients of horizontal soil columns from natural saline-alkaline wetland in a semiarid area. Eurasian Soil Science. 2007, 40(6): 660-664.

[2] Bai J., Ouyang H., Wang Q., Zhou C., Xu X. Spatial variations in daily average CO_2 concentrations above wetland surface of Xianghai

National Nature Reserve, China. Journal of Environmental Sciences-China. 2005, 17(1): 54-58.

[3] Wang Y., Chai F., Liu H., Wang Y.. Analysis on the characteristics of horizontal transport of the atmospheric pollutant over the Yangtze Delta. Resarch of Environmental Sciences. 2008,21(1):22-29.

[4] Gao Y., He J., Wang Z. Simulation for impact of urbanization on meteorological conditions in Beijing area. Journal of Meteorology and Environment. 2007,23(3):58-64.

[5] Lin T., Zhang Y., Yang X., Zhao H., Li X., Ji X. The application of MM5 model to predict sea surface wind field. Marine Forecasts. 2004,21(4):1-9.

[6] Tang L., LAM K.S. Zhan J.M., LI Y.S. Application of mesoscale model MM5 to a cold front weather system. Acta Scientiarum Naturalium Universitatis Sunyatseni.2007,46 (6): 114-118.

[7] Shen P., Gao A. The integration of results of different initial data for meso-scale model MM5 to imitate huanghuai cyclone. Scientia Meteorological Sinica 2007,27(2):140-146.

[8] Jiao L. Zhang Yonggang. An evaporation duct prediction model coupled with the MM5. Acta Meteorological Sinica.2009,67(3):382-387.

[9] Ministry of Environmental Protection. Guidelines for Environmental Impact Assessment of Atmospheric Environment. China Environmental Science Press.2008.

[10] PSU/ NCAR Mesoscale Modeling System Tutorial Class Notes and Use’s Guide：MM5 Modeling System Version 3. National Center for Atmospheric Research，January 2002.

[11] Zhu X., Zhang W., Song J. Research on the distributed parallel computation of the mesoscale numerical weather prediction model MM5. Journal of National University of Defense Technology. 2003,25(2):56-67.