INFLUNCE OF THE TOPOGRAPHIC INTERPOLATION METHODS ON HIGH-RESOLUTION WIND FIELD SIMULATION WITH SRTM ELEVATION DATA OVER THE COASTAL AREA

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ABSTRACT: High-resolution mesoscale meteorological modeling requires more accurate and higher resolution digital elevation model (DEM) data. Shuttle Radar Topographic Mission (SRTM) has created 90 m DEM for entire globe and that is freely available for meteorological modeling and environmental applications. In this research, the effects of the topographic interpolation methods on high-resolution wind field simulation in the coastal regions were quantitatively analyzed using Weather Research and Forecasting (WRF) model with SRTM data. Sensitivity experiments with three different interpolation schemes (four-point bilinear, sixteen-point overlapping parabolic and nearest neighbor interpolation methods) were preformed using SRTM. In WRF modeling with sixteen-point overlapping parabolic interpolation, the coastal line and some small islands show more clearly than other cases. The maximum height of inland is around 140 meters higher, while the minimum of sea height is about 80 meter lower. As it concerns the results of each scheme it seems that the sixteen-point overlapping parabolic scheme indicates the well agreement with observed surface wind data. Consequently, topographic changes due to interpolation methods can lead to the significant influence on mesoscale wind field simulation of WRF modeling.

KEY WORDS: SRTM, WRF, Coastal areas, Wind field simulation

1. INTRODUCTION

High-resolution mesoscale meteorological modeling requires more accurate and higher resolution topography data. It plays an important role to generate the realistic local winds in the presence of both land/sea-breeze and mountain/valley-wind mechanisms in coastal regions. In WRF meteorological modeling has typically used low resolution topography data (~1km) obtained from US Geological Survey (USGS-30s). It lacks the precision required for high resolution (less than 1km) wind field modeling (LAM, 2006). Also, Light Detection and Ranging (LiDAR) with lasers mounted on small aircraft generates high resolution geographic data (less 1km), but it is comparably expensive due to non-technology constrains such as flight and ground-calibration costs (Stephen, 2003). However, the development of remote sensing and digital image techniques has brought the new era of the high resolution meteorology modeling (Rabus et al., 2003) since producing high resolution of digital elevation data set such as Shuttle Radar Topographic Mission (SRTM).

In such SRTM applications of the high resolution wind field simulation, the fundamental requirement is to represent the terrain surface such that elevations can be retrieved for any given grid point. In addiction, more accurate high resolution geographic data with the optimal interpolation method can be attributed to increase the accuracy of forecasting complex meteorological interaction considering the realistic coastal line over coastal areas. The purpose of this research is to analysis the effect of SRTM-3s topographic data interpolated in high resolution wind field simulation. The first part of this paper demonstrates the effect of the SRTM application on WRF model for simulating high resolution wind field over coastal areas, and then evaluates the influence of a variety of alternative interpolation filters such as nearest neighbour, four-point bi-linear, sixteen-point overlapping bi-linear interpolation that attempt to derive the shape of the surface at interpolated points on wind simulation.

2. METHODOLOGY

2.1 SRTM data

The Shuttle Radar Topography Mission (SRTM) is an international joint project spearheaded by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) to map the world in three dimensions. To acquire topographic (elevation) data, the SRTM payload was outfitted with two radar antennas. One antenna was located in the shuttle's payload bay, the other on the end of a 60-meter (200-foot) mast that extended from the payload pay once the Shuttle was in space. With its radars sweeping most of the Earth's surfaces, SRTM used dual Space borne Imaging Radar (SIR-C) and dual X-band Synthetic Aperture Radar (X-SAR) configured as a baseline interferometer, acquiring two images at the same time (Farr and Kobrick, 2000; Werner, 2001).

SRTM data is being used to generate a digital topographic map of the Earth's land surface with data points spaced every 3 arc second for Global coverage of latitude and longitude (approximately 90 meters). The SRTM "finished" data meet the absolute horizontal and vertical accuracies of 20 meters (circular error at 90% confidence) and 16 meters (linear error at 90%

confidence), respectively, as specified for the mission. The vertical accuracy is actually significantly better than the 16 meters. It is closer to +/- 10 meters. It is freely available for meteorology modeling and environmental application from web site (http://seamles s.usgs.gov)

2.2 Model description

The Weather Research and Forecasting (WRF) model is designed to be a flexible, state-of-the-art atmospheric simulation system. In particular, WRF version 3.0.1, used in this paper, offers a new interpolating and physics options (ARW, 2008). WRF model is running over three two-way multi-nested domains with increasing horizontal resolutions of 10km (D01), 3.3km (D02), 1.1km (D03) and 1.1km (D04) (Figure 1). 28 hybrid sigma pressure levels are considered on the vertical up to 50hpa. The initial meteorological condition was determined using 3-h the regional data assimilation and prediction system (RDAPS) at 30 km (latitude, longitude), which was provided by KMA. The surface boundary condition for Noah-LSM (Land Surface Model) was used 6-h global final analysis (FNL) at 1.0 degree (latitude, longitude) generated by NCEP. The daily SST observations obtained from the National Centers for Environmental Prediction/Marine Modeling and Analysis Branch (NCEP/MMAB). The microphysical subgrid processes are represented by the scheme described by Lin et al (1983). Kain-Fritsch cumulus parameterization scheme is employed only for D01. For planetary boundary layer and surface physics, Yonsei University PBL and Noah LSM surface schemes are respectively used. The WRF simulation was performed for the period of 0000 LST 23 – 26 August 2007 for the dominant sea breeze circulation event.

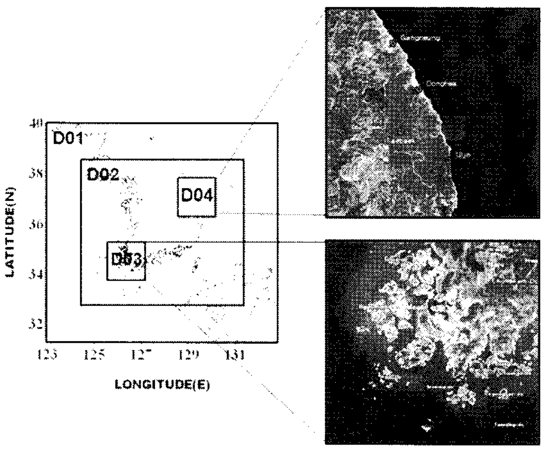

Figure 1. The nested model domains for WRF simulation. Domain 1, 2, 3 and 4 (denoted by D01, D02, D03 and D04) have a horizontal grid resolution of 10, 3.3, 1.1, 1.1 km, respectively. Domain is enlarged from the left to the lower right (D03) and the upper right (D04) for showing topography in the model area.

2.3 Experimental design

First, the sensitivity analysis of SRTM was examined by comparing with USGS which has been typically used in WRF model. Second, four numerical modeling experiment using three different interpolation methods were performed (Table 1). The following table gives a summary of numerical experiments for this paper, and the detail description of each interpolating scheme is below.

Table1. A summary of numerical experiments

Experiment	Interpolation method	Data
EXP0	4-point bi-linear	USGS-30s
EXP1	4-point bi-linear	SRTM-3s
EXP2	16-point overlapping parabolic	SRTM-3s
EXP3	Nearest neighbour	SRTM-3s

For EXP1and EXP2, four-point bi-linear interpolation was used for USGS and SRTM elevation data. It needs four valid source points a_{ij}, $1 \le i, j \le 2$, surrounding the model grid point(x,y), to which geogrid must interpolate, as illustrated in the Figure 2 below. In mathematics, bilinear interpolation is an extension of linear interpolation for interpolating functions of two variables on a regular grid. The key idea is to perform linear interpolation first in one direction and then again in the other direction. The result of bilinear interpolation is independent of the order of interpolation. Intuitively, the method works by linear interpolation to the y-coordinate of the point(x,y) between a11 and a_{12}, and between a_{21} and a_{22}, and then to the x-coordinate, the resulting approximation would be the same (ARW,2008).

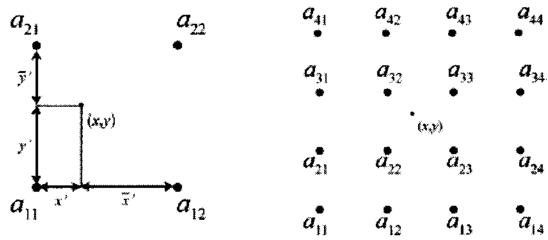

Figure 2. 4-point bi-linear and 16-point overlapping parabolic interpolation method's calculation grid.

In EXP3, sixteen-point overlapping parabolic interpolation is used for SRTM. It requires sixteen valid source points surrounding the point(x,y), as illustrated in the Figure 2. The method works by fitting one parabola to the points a_{i1}, a_{i2}, and a_{i3}, and another parabola to the points a_{i2}, a_{i3}, and a_{i4}, for row I, $1 \le i \le 4$;then, an intermediate interpolated value pi, within row I at the x-coordinate of the point is computed by taking an average of the values of the two parabolas evaluated at x, with the average being weighted linearly by the distance of x between a_{i2}, and a_{i3}. Finally, the interpolated value at (x,y) is found by performing the same operations as for a row of points, but for the column of interpolated values pi to the y-coordinate of (x,y) (ARW, 2008). In EXP4, nearest neighbour interpolation method simply sets the interpolated value at model grid point to the value of the nearest source data point, regardless of whether this nearest source point is valid, missing, or masked (Shi, 2007).

3. RESULT

3.1 The sensitivity analysis of SRTM

The entirely difference between SRTM and USGS elevation data, generated from WRF meteorological modeling, shows in Figure 3 and Figure 4 with the original SRTM DEMs. Overall both domain D03 and D04 have different topography, but some interesting figures using three interpolation schemes can be seen in this result.

At Figure 3, the improvement after application of SRTM (B) is more perceptible in the detail coastal line than USGS (A), compared with the original SRTM (D) DEMs. SRTM topography shows more clearly the shape of several small islands in comparison with USGS data-based topography. The mean, maximum and minimum height difference between EXP0 and EXP1 at Figure 3 is 4.67 m, 105.68 m, -56.285 m, respectively (not shown in this paper). In the difference between EXP0 and EXP1, the topography height of EXP1 is generated higher than EXP0 in the landfill and mountainous area, lower in the near coastal areas. It can be seen that SRTM considerably influenced in the complex coastal area for interpolating the realistic topography.

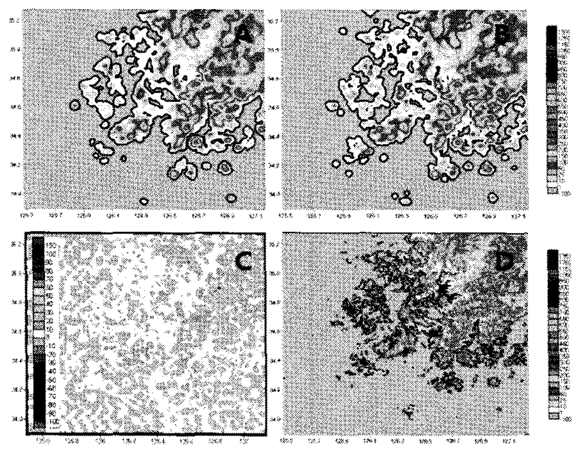

Figure 3. Topography of D03 for EXP0 (A) and EXP1 (B), and the height differences between EXP0 and EXP1 (C) and original SRTM (D) DEMs (contour interval 10m; units in meters; rectangular projection)

Figure 4 was shown the topography of the domain D04 at EXP0 (A) and EXP1 (B). The mean, maximum and minimum height difference between EXP0 and EXP1 (C) at Figure 4 is 3.72 m, 108.92 m, -234.43 m, respectively (not shown in this paper). It is no significant difference or improvement effect using SRTM data on the simple coastal line area such as East Sea. However, in the Southwest area having complex coastal line (domain D03), the use of SRTM high resolution data gives more realistic coastal shape on meteorological modeling in comparison with the original SRTM.

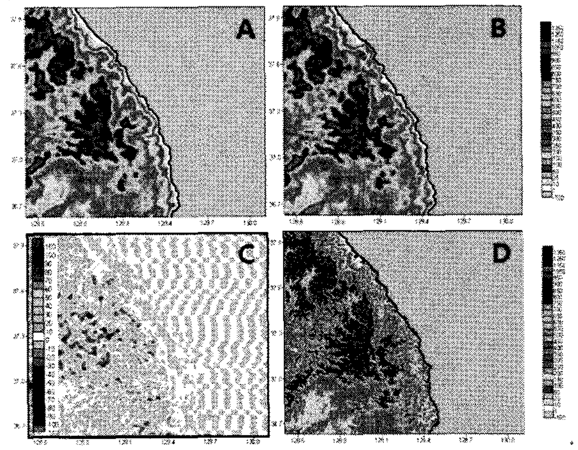

Figure 4. The same as Figure 3, but for D04

The two histograms in Figure 5 (D03 for Southwest area, D04 for East Sea area) show the classification distribution to which interpolation method generates the more realistic elevation on meteorology modeling. The maximum is 1500 m and the minimum is 0, and the sum of percentage is 100 with 100m interval. Classification result for 0-100m of height difference in D03 is covering at approximately 88% of the original SRTM, 56% for EXP2, 55% for EXP1, 54% for EXP3, respectively. The large percent of original SRTM is lower than 100m, and the gap with EXP1, EXP2, and EXP3 is over 20 %. The height difference of 0-100m in D03 was the results that the amount of coastal area near costal line was processed from sea to land such as reclaiming in interpolating work in WRF model (Figure 3). However, in D03, the original SRTM is a smaller percentage in 100-600m than EXP1, EXP2, and EXP3. It is caused of the large reclaimed land near coastal area of EXP1, EXP2, EXP3 processed by each interpolating method. Moreover, obtaining results show that the height difference with different interpolation methods for SRTM is quite significant in the complex coastal area (D03). On the other hand, there is no definite effect using different interpolating methods for the simple coastal line area (D04).

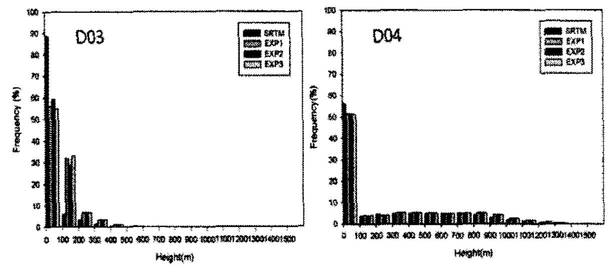

Figure 5. Frequency histogram for classification results of height difference, the domain D03 (left) and D04 (right) with SRTM, EXP1, EXP2, and EXP3 (classification including both land and sea area)

3.2 Analysis of horizontal wind field

In Figure 6, in the coastal area, wind speed and direction slightly differ from each experiment. It appeals that the elevation changes from different interpolation methods and the use of high resolution data influenced the geographical characters such as the maximum height, the location of small islands, and the shape of coastal line in modeling process. It easily affects on the wind flows in coastal area. However, it is hard to know which interpolation method is the optimal for SRTM data in this research using the one meteorological model. Thus, in further study, it needs to perform more various experiments using several meteorological models with similar interpolation schemes and diagnostic equations, and the sensitive analysis with the observation data.

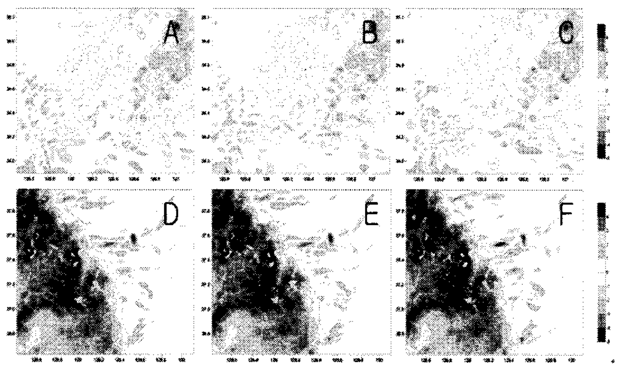

Figure 6. Wind field difference for D03 (above) between EXP0 and EXP1(A), EXP2(B), EXP3(C), and for D04 (below)between EXP0 and EXP1(D), EXP2(E), EXP3(F).

4. CONCLUSION

In this paper, SRTM elevation data was applied for high resolution wind field simulation on WRF meteorology model with different three interpolation filters. The result of experiments gives some interesting figures to process the high resolution wind field simulation. The result with respect to this study can develop to simulate the wind field simulation for complex coastal terrain regions with resolutions higher than 1km.

This work constitutes a step in the direction of understanding the use of elevation data in atmospheric model, and the use of geographical information system (GIS) for digital elevation models (DEMs) is a powerful approach in this study area, because automatic methods to analyze topographic features are dealt with both operational and quality advantages. At the last, future work will be needed to understanding of the effect of various geographical remote sensed observation data on mesoscale atmospheric model.

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