World Academy of Science, Engineering and Technology
International Journal of Computer and Systems Engineering
Vol:9, No:12, 2015

Development of a Wind Resource Assessment Framework Using Weather Research and Forecasting (WRF) Model, Python Scripting and Geographic Information Systems

Jerome T. Tolentino, Ma. Victoria Rejuso, Jara Kaye Villanueva, Loureal Camille Inocencio, Ma. Rosario Concepcion O. Ang

Open Science Index, Computer and Systems Engineering Vol:9, No:12, 2015 publications.waset.org/10003050/pdf

***Abstract*—**Wind energy is rapidly emerging as the primary source of electricity in the Philippines, although developing an accurate wind resource model is difficult. In this study, Weather Research and Forecasting (WRF) Model, an open source mesoscale Numerical Weather Prediction (NWP) model, was used to produce a 1-year atmospheric simulation with 4 km resolution on the Ilocos Region of the Philippines. The WRF output (netCDF) extracts the annual mean wind speed data using a Python-based Graphical User Interface. Lastly, wind resource assessment was produced using a GIS software. Results of the study showed that it is more flexible to use Python scripts than using other post-processing tools in dealing with netCDF files. Using WRF Model, Python, and Geographic Information Systems, a reliable wind resource map is produced.

***Keywords*—**Wind resource assessment, Weather Research and Forecasting (WRF) Model, python, GIS software.

I. Introduction

NOWADAYS, investments in renewable energy are growing faster. Not only that it cuts the electric bill but it also cleans the Earth's climate. Moreover, there are many sources of renewable energy and one of its sources is wind energy. Wind energy is always present because of uneven heating of the Earth by the Sun. Therefore, using wind energy as source of renewable energy is one of the best options. In addition, the Philippines is one of the countries that is rapidly developing wind as a primary source of electricity. However, assessing wind energy in a particular domain poses a tough challenge to the developers and researchers. With the help of numerical weather prediction (NWP), it can determine the wind resource potential because it uses numerical representation of the atmosphere based on current weather measurements.

Based on researches, WRF model performance is better than MM5 [1]. The Weather Research and Forecasting (WRF) Model is an open source NWP system used for research and operational applications. It is fully compressible and is a nonhydrostatic model with vertical coordinates of terrain-following hydrostatic pressure [2]. The numerical methods the model use are 2nd and 3rd order Runge-Kutta scheme. For the horizontal and vertical, a 2nd to 6th order advection scheme is used. The model supports ideal and real case application. The model also supports nesting mode (one-way, two-way, and moving nest options). The WRF Modeling System workflow is shown in Fig. 1.

The WRF output is in netCDF format - a representation of scientific variables in an array-oriented data. Since the WRF model output is considered a meteorological data, there are many scientific variables modeled, one of which is the wind speed. It consumes larger file size to the system thus an extraction of wind speed in the WRF output is needed. There are many post-processing tools that can handle netCDF files. First is the Panoply netCDF viewer, it can only visualize netCDF output but cannot extract and manipulate wind speed. Second is by using a GIS software, it supports netCDF files but opening such large files are time consuming. Also, it is incapable of manipulating wind speed like calculating its annual mean wind speed. Lastly, Grid Analysis and Display System (GrADS), is an open source post-processing tool used to access, manipulate and visualize earth science data like netCDF. However, creating scripts for these are very complex.

Python is widely used by researchers and software engineers because of its object-oriented open source programming language. It can handle earth science data like netCDF and Grib [3]. Being object oriented, its command is easier and compact compared to other programming language. In this paper, python script was used in extracting wind speed from a WRF output (netCDF) file [4].

A. Objectives of the Study

This study aims to produce a wind resource map using WRF model, Python scripting and GIS software. Simulation, extraction, and visualization are the three main parts of the study. For simulation, WRF model was used with recommended parameterization by several literatures. For extraction of wind speed, Python-based GUI software was developed. Lastly, a GIS environment was used for visualization.

Jerome T. Tolentino, Ma. Victoria Rejuso, Jara Kaye Villanueva, Lourel Camille Inocencio, and Ma. Rosario Concepcion O. Ang are with the Phil-LiDAR 2 REMap: Philippine Renewable Energy Resource Mapping from LiDAR Surveys and UP Training Center for Applied Geodesy and Photogrammetry (UP TCAGP), University of the Philippines, Diliman, Quezon City, 1101, Metro Manila, Philippines, (e-mail: tolentinojeromet@gmail.com).

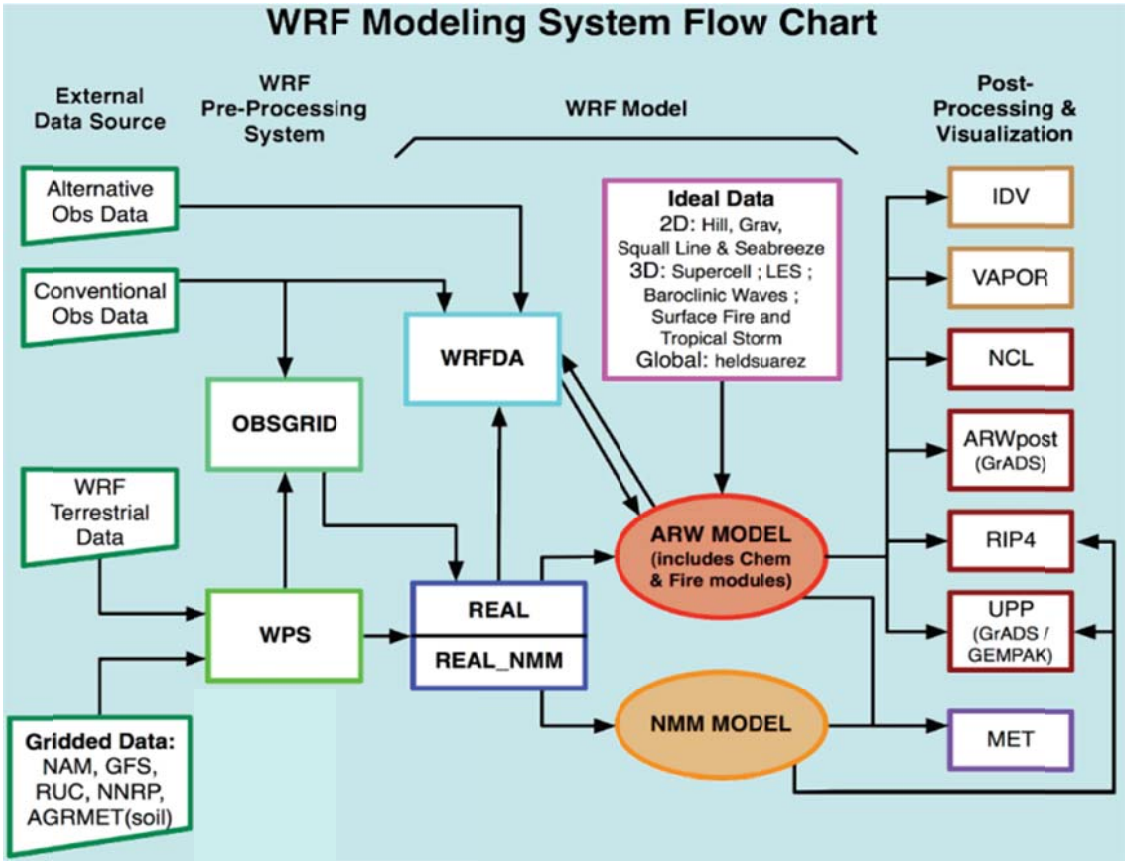


Fig. 1 WRF Modeling System Workflow

Specifically, the objectives of the study are:

1. To simulate 1-year atmospheric data using WRF model,
2. To extract annual mean wind speed on the WRF output using Python,
3. To develop a wind resource map using GIS environment.

B. Scope and Limitations

The study focuses on developing wind resource map using WRF model, Python scripting and GIS. The simulated area was 2014 of Ilocos region with 4 km resolution. The input data for WRF model was downloaded from NCAR website. Simulation and extraction was done using Ubuntu platform.

II. Methodology

This study has three main parts: simulation, extraction and visualization. WRF model was used to simulate meteorological data with 1-year 4 km resolution in Ilocos region. Then, the WRF output was extracted using Python and eventually stored in an Excel file. Lastly, GIS environment was used to develop an annual mean wind resource map.

A. WRF Model

WRF Model version 3.6 was used in the study. In the WRF model, there are three major components to its workflow: WRF pre-processing (WPS), WRF model, and Post-processing. The time period for WRF simulation is from January 1, 2014 to January 1, 2015 with an hourly output [5]. Nesting domain was used in WRF model to have 3 domains with resolutions, 36 km, 12 km and 4 km respectively. The selected domains are shown in Fig. 2.

The 1st domain selected covered almost the entire Luzon and Visayas part of the Philippines. Then, the 2nd domain selected covered the Luzon part of the Philippines excluding the Palawan area. Lastly, the 3rd domain selected covered the upper part of Luzon which includes the Ilocos region. All of the domains had 28 vertical levels with geographic resolution of 10m, 5m and 2m respectively.

In this study, adaptive time step was used to have faster simulation. In microphysics parameterization, WSM6 microphysics was used because it is recommended for higher resolution simulations [1]. In addition, it has the lowest RMSE for wind speed compared to WSM5 microphysics [1]. For cumulus parameterization, Kain-Fritsch was selected because it was recommended by UMD and EPA [1]. For the other parameterization schemes, the study used the default parameters of the WRF Domain Wizard.

B. Extraction Using Python

A developed Python-GUI based software was used in the extraction of wind speed from WRF output (netCDF) [6]-[8]. Tkinter library was used in creating GUI software [6]. The main window of the software is shown in Fig. 3.

Open Science Index, Computer and Systems Engineering Vol:9, No:12, 2015 publications.waset.org/10003050/pdf

Open Science Index, Computer and Systems Engineering Vol:9, No:12, 2015 publications.waset.org/10003050/pdf

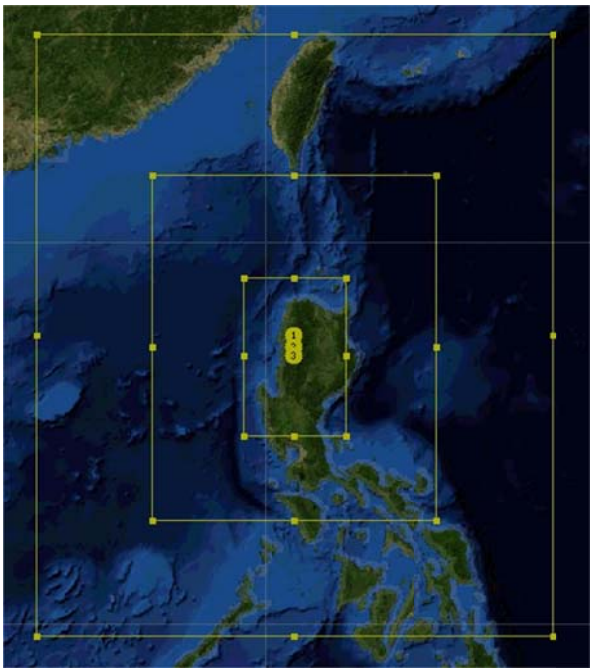


Fig. 2 Three selected domains (36 km, 12 km and 4 km resolution respectively)

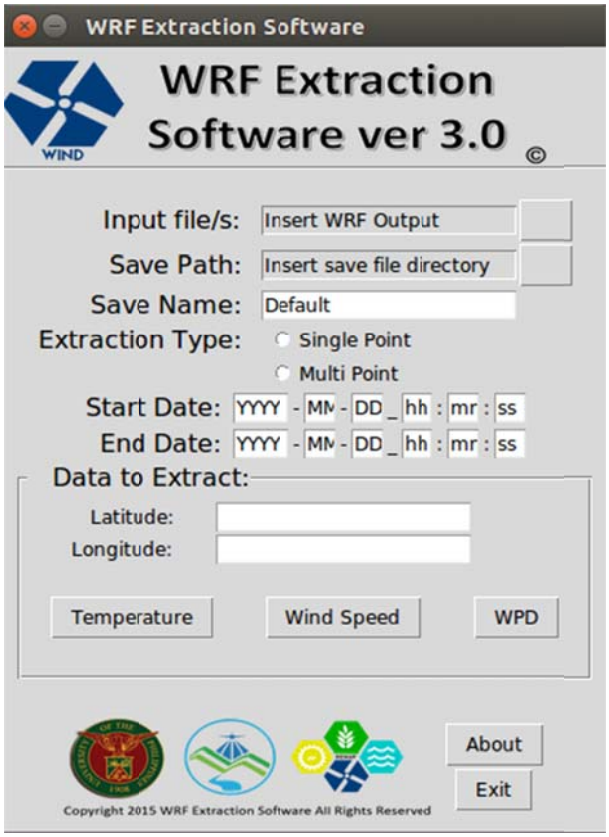


Fig. 3 WRF Extraction Software version 3 main window

The software can extract wind speed, wind power density (WPD) and temperature from a WRF output. However, for this study, only wind speed was extracted from the WRF output. An annual mean wind speed will be extracted from the WRF output (netCDF) which will be later stored in an Excel format.

C. Visualizing Using GIS Software

An open source GIS based software was used in developing wind resource map. Using the extracted annual mean wind speed in Excel, the data will be added with a projection of WGS 1984. Then, an interpolation method will be used to have a smooth raster data.

III. Results and Discussion

The simulation time was approximately 2 weeks using 8 logical processors and adaptive time step. The extraction of the annual mean wind speed using the Python-GUI based software was faster (seconds) than using a GIS environment software (minutes) [9]. This shows that using a python script is more lightweight than using a GIS environment software. The extracted wind speed was shown in Fig. 4. It shows that there is a particular wind speed for every longitude and latitude. Also, the distance of each point was 4 km because the 3rd domain is in 4 km resolution.

	Lon	Lat	Average Wind Speed(10m)
2	119.4296494	15.1166153	4.518041284
3	119.4674072	15.1166153	4.513503157
4	119.5051651	15.1166153	4.507063407
5	119.542923	15.1166153	4.494308231
6	119.5806732	15.1166153	4.478749562
7	119.6184311	15.1166153	4.466794315
8	119.656189	15.1166153	4.466649227
9	119.6939468	15.1166153	4.492336772
10	119.7316971	15.1166153	4.512454342

Fig. 4 Extracted Annual Mean Wind Speed of Ilocos 2014

After analyzing the extracted data, an annual mean wind resource map was made with minimum (1.84 m/s) and maximum (8.94 m/s) wind speed. As shown in Fig. 5, the wind speed from the sea surface is faster compared to the wind speed from the land surface which is due to the more surface roughness in water compared to land. Furthermore, the area of the highest wind speed on the land surface has higher elevation due to Mt. Sicapoo in Cordillera. This shows that areas with higher elevation have higher wind speed values due to lesser obstacles compared to those areas with lower elevation. To further analyze and validate the wind resource map, there is already an existing wind farm in Bangui, Ilocos Region which was shown as a point data in Fig. 5. Therefore, we can say that the WRF model simulation is a reliable way to assess wind resource available in an area.

IV. Conclusion

A 1-year atmospheric simulation with 4 km resolution on Ilocos Region, Philippines was processed using WRF Model 3.6. Then, annual mean wind speed was extracted using the developed Python-GUI based software which is faster than using GIS software. Since the extracted output was in Excel,

manipulating data is easier and flexible. Lastly, wind resource map was produced by interpolating the point data to a raster data. It can be concluded that a reliable wind resource map can be produced using WRF model, Python, and GIS software.

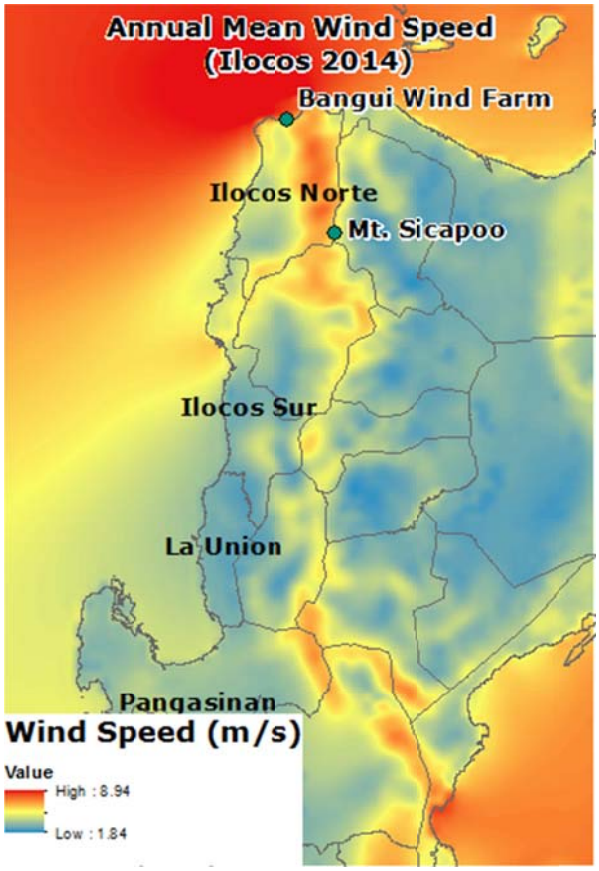


Fig. 5 Annual Wind Resource Map in Ilocos

V. Recommendation

For better wind speed accuracy, the author recommends to increase the vertical levels of the domain in the WRF model. Furthermore, validation of simulated wind speed output to observed wind speed is needed for improving its accuracy. In addition, the author recommends to next produce a site suitability map to identify the best location in developing future wind farms.

Acknowledgment

The study was under full consultation with Dr. Gerry Bagtasa of Institute of Environmental Science and Meteorology, University of the Philippines-Diliman. This research is also part of the Phil-LiDAR 2 Program under the Department of Science and Technology. This research is an output of the Nationwide Detailed Resources Assessment using LiDAR Program (Phil-LiDAR 2), in particular, Project 5: Philippine Renewable Energy Resource Mapping from LiDAR Surveys (REMap). The Program is funded by the Department of Science and Technology (DOST) through its grants-in-aid program (GIA) and implemented by the Training Centre for Applied Geodesy and Photogrammetry of the University of the Philippines – Diliman. We are grateful to the DOST for the financial support given.

References

[1] D. B. Mde, T. D. M. Dep, M. K. N. Dec, W. H. N. Dec, G. S. N. Dec, M. K. V. Deq And D. B. I. Dnr, "Sensitivity testing of WRF physics parameterizations for meteorological modeling and protocol in support of regional SIP air quality modeling in the OTR," 2009.

[2] W. Wang, C. Bruyere, M. Duda, J. Dudhia, D. Gill, H. C. Lin and J. Mandel, "ARW version 3 modeling system user's guide. Mesoscale & Miscroscale Meteorology Division. National Center for Atmospheric Research," January 2015. (Online). Available: http://www.mmm.ucar.edu/wrf/users/docs/user_guide_V3/ARWUsersGuideV3. (Accessed 17 October 2015).

[3] J. W. B. Lin, "Why python is the next wave in earth sciences computing," Bulletin of the American Meteorological Society, vol. 93, no. 12, pp. 1823-1824, 2012.

[4] M. Rainer, "Multidimensional Marine Environmental Data Conversion and Visualization Using Python and GIS".

[5] N. C. f. E. P. W. S. D. o. C. C. f. E. P. W. S. D. o. Commerce, "NCEP FNL Operational Model Global Tropospheric Analyses, continuing from July 1999," Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory, 2000, updated daily. (Online). Available: http://dx.doi.org/10.5065/D6M043C6. (Accessed 17 10 2015).

[6] J. W. Shipman, "Tkinter reference: a GUI for Python," Technical report, New Mexico Tech Computer Center, 2005.

[7] "netCDF4 module," (Online). Available: http://unidata.github.io/netcdf4-python/ (Accessed 17 October 2015).

[8] J. McNamara, "Creating Excel files with Python and XlsxWriter," (Online). Available: http://xlsxwriter.readthedocs.org/ (Accessed 1 July 2015).

[9] G. Zhao, B. A. Bryan, D. King, X. Song and Q. Yu, "Parallelization and optimization of spatial analysis for large scale environmental model data assembly," Computers and electronics in agriculture, vol. 89, pp. 94-99, 2012.

Open Science Index, Computer and Systems Engineering Vol:9, No:12, 2015 publications.waset.org/10003050/pdf