PREPARED FOR
AWS TRUEPOWER, LLC, SOCIALIST REPUBLIC OF VIETNAM

WIND RESOURCE ATLAS OF VIETNAM

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PREPARED BY
AWS Truepower, LLC

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EXECUTIVE SUMMARY

In 2002, the Ministry of Industry and Trade (MOIT) and Electricity of Vietnam (EVN) released “Vietnam: Renewable Energy Action Plan,” or REAP, a 10-year program aimed at expanding the use of renewable energy sources in Vietnam. As part of its effort to advance wind energy under the REAP, the Ministry of Industry and Trade (MOIT), with the support of the World Bank, awarded a contract in October 2007 to carry out a “Wind Resource Assessment at Selected Sites in Vietnam.” The project, performed by a team including GPCO (Canada), AWS Truepower (USA), and ENERTEAM (Vietnam), with PECC3 (Vietnam) as a sub-consultant, led to the selection of three promising wind project sites, followed by a two-year wind-monitoring program, which was completed at the end of 2010.

In early 2010, MOIT, with the support of the World Bank, awarded a contract to AWS Truepower to create a new Wind Resource Atlas of Vietnam. The main goal of this project was to update the previous Wind Energy Resource Atlas of South East Asia (2001) using state-of-the-art methods verified by the latest available wind measurements. In addition, the project aimed to make the wind resource maps available to developers and other interested groups through an interactive web site.

To accomplish this objective, AWS Truepower ran a mesoscale-microscale modeling system called ***MesoMap®*** over Vietnam, producing maps of mean wind speeds at 60 m, 80 m, and 100 m with a horizontal spatial resolution of 200 m. AWS Truepower validated the wind maps by comparing the predicted speeds with measured values from nine towers, including eight tall towers instrumented for wind energy assessment. The predicted mean wind speeds at 80 m were on average 0.24 m/s less than the observed mean wind speeds projected to the same height, and the standard deviation of the biases was 0.84 m/s. Based on these findings, the standard error of the maps is estimated to be 0.8 m/s.

According to the new maps, the most promising areas for wind development in Vietnam are along the southern and south-central coasts and in mountain gaps in central Vietnam. Along exposed coastal points of south-central Vietnam, the mean win speed at 80 m height is predicted to reach 6.5 m/s to 7.0 m/s. Another area of better-than-average winds (5.0 m/s to 6.0 m/s) is along the coast near Can Tho. A third area of significant interest (6.0 m/s to 6.5 m/s) is the broad mountain gap west of Binh Dinh along the Dac Lac and Gia Lai provincial border. Farther to the north, the best wind resources are confined mainly to the coast near Quang Binh and southeast of Ha Noi.

The Wind Resource Atlas of Vietnam is made available through an internet-based platform called the Vietnam ***windExplorer***. Using this interface, registered users can browse the wind speed maps and click to view values of mean wind speed, elevation and roughness, as well as view charts of mean wind speed by month and frequency by direction. The site is administered by MOIT and will served by AWS Truepower for three years.

The accuracy of the wind resource maps could be improved through continued data gathering and analysis. AWS Truepower recommends a new meteorological data gathering campaign to supplement the recently concluded MOIT wind resource assessment project. Monitoring should be focused in areas of potential importance for wind energy development, and especially areas that have not previously been previously monitored under the MOIT program.

INTRODUCTION

In 2001, AWS Truepower, then under the name TrueWind Solutions, created the Wind Energy Resource Atlas of South East Asia under contract to the World Bank. The purpose of the atlas was to facilitate the development of wind energy both for utility-scale generation and distributed power by providing information on the magnitude and distribution of wind energy resources. The atlas provided wind speed maps and meteorological characteristics for four countries: Cambodia, Laos, Thailand, and Vietnam. An analysis accompanying the atlas suggested that of the four countries Vietnam has the greatest wind energy generation.

In 2002, the Ministry of Industry and Trade (MOIT) and Electricity of Vietnam (EVN) released "Vietnam: Renewable Energy Action Plan," or REAP, a 10-year program aimed at expanding the use of renewable energy sources in Vietnam. In recent years, under REAP and related policy initiatives, several thousand megawatts of renewable energy projects have been installed in Vietnam, with the encouragement of the Government of Vietnam. The vast majority of this development has been in the form of hydropower.

As part of its effort to advance wind energy under the REAP, the Ministry of Industry and Trade (MOIT), with the support of the World Bank, issued in 2005 a Request for Proposals for a "Wind Resource Assessment at Selected Sites in Vietnam." After a competitive process, the project was awarded in October 2007 to a team consisting of GPCO (Canada, team leader), AWS Truewind (USA) and ENERTEAM (Vietnam), with PECC3 (Vietnam) as a sub-consultant. The objective of the project was to identify and assess candidate wind project sites to facilitate the development of a pilot wind energy project. This addressed two barriers to wind energy development identified in the REAP: inadequate awareness of the technologies, in particular their costs and performance; and a lack of hard data concerning wind resources.[1] The project led to the selection of three promising wind project sites, followed by a two-year wind-monitoring program, which was completed at the end of 2010.[2]

By the end of 2009, after just one year of measurement had been completed, it was observed that the Wind Atlas of Southeast Asia had probably overestimated the wind resource at these three sites, and by implication in other regions of Vietnam. Partly in response to this finding, in early 2010, MOIT, with the support of the World Bank, awarded a contract to AWS Truepower to create a new Wind Resource Atlas of Vietnam. The main goal of this project was to update the assessment of Vietnam's wind resources using state-of-the-art methods verified by the latest available wind measurements. In addition, the project aimed to make the wind resource maps available to developers and other interested groups through an interactive web site.

This report describes the methods used to develop the Wind Resource Atlas, presents the wind maps, updates estimates of the wind resource potential, and describes the interactive web site that has been created, which is called the Vietnam *windExplorer*.

METHOD

The Wind Resource Atlas of Vietnam was created using AWS Truepower's MesoMap system. This system was developed to map the wind resources of large regions at a high level of detail with good accuracy.

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[1] Vietnam: Renewable Energy Action Plan, ESMAP Technical Paper 021, World Bank (Washington, DC, 2002), p. 10.

[2] Reference final WRA report

The Wind Energy Resource Atlas of Southeast Asia was its first major application. The present project was carried out using an updated version that achieves higher resolution and improved accuracy.

The mapping process is summarized in Figure 1 (read left to right). The following sections discuss the process in detail.

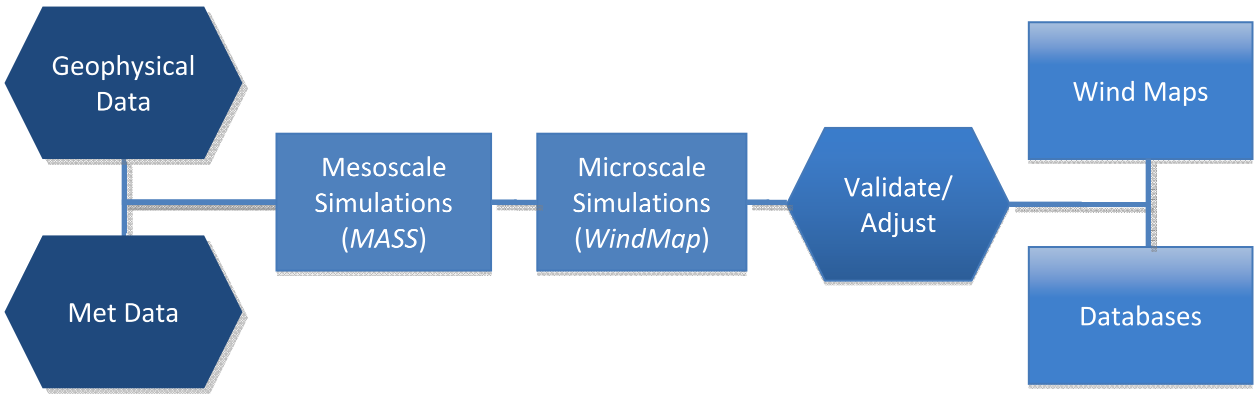

Figure 1. Schematic of the MesoMap system used to produce the Wind Resource Atlas of Vietnam. The diagram is read left to right.

MesoMap Components

The MesoMap system has three main components: models, databases, and computer systems.

Models

At the core of the MesoMap system is MASS, a numerical weather model that has been developed over the past 20 years by AWS Truepower's partner MESO, Inc., both as a research tool and to provide commercial weather forecasting services.[3] MASS simulates the fundamental physics of the atmosphere including conservation of mass, momentum, and energy, as well as the moisture phases, and it contains a turbulent kinetic energy module that accounts for the effects of viscosity and thermal stability on wind shear. A dynamic model, MASS simulates the evolution of atmospheric conditions in time steps as short as a few seconds. This creates great computational demands, especially when running at high resolution. Hence MASS is usually coupled to a simpler but much faster program, WindMap, a mass-conserving wind flow model developed by AWS Truepower.[4] Depending on the size and complexity of the region and requirements of the client, WindMap is used to improve the spatial resolution of the MASS simulations to account for the local effects of terrain and surface roughness variations.

Data Sources

MASS uses a variety of online, global, geophysical and meteorological databases. The main meteorological inputs are reanalysis data, rawinsonde data, and land surface measurements. The reanalysis database – the most important – is a gridded historical data set produced by the

[3] Manobianco, J., J. W. Zack and G.E. Taylor, 1996: Workstation-based real-time mesoscale modeling designed for weather support to operations at the Kennedy Space Center and Cape Canaveral Air Station. Bull. Amer. Meteor. Soc., 77, 653-672. Embedded equations are described in Zack, J., et al., 1995: MASS Version 5.6 Reference Manual. MESO, Inc., Troy, NY.

[4] Brower, M.C., 1999: Validation of the WindMap Model and Development of MesoMap, Proc. of Windpower 1999, American Wind Energy Association, Washington, DC.

US National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR).[5] The data provide a snapshot of atmospheric conditions around the word at all levels of the atmosphere in intervals of six hours. Along with rawinsonde and surface data, the reanalysis data establish the initial conditions as well as lateral boundary conditions for the MASS runs. The MASS model itself determines the evolution of atmospheric conditions within the region based on the interactions among different elements in the atmosphere and between the atmosphere and the surface. The reanalysis data are on a relatively coarse grid (about 210 km spacing). To avoid generating noise at the boundaries that can result from large jumps in grid cell size, MASS is run in several nested grids of successfully finer mesh size, each taking as input the output of the previous nest, until the desired grid scale is reached. The outermost grid typically extends several thousand kilometers.

The main geophysical inputs are elevation, land cover, vegetation greenness (normalized differential vegetation index, or NDVI), soil moisture, and sea-surface temperatures. The elevation data used by MASS and WindMap are from the Shuttle Radar Topographical Mission (SRTM), an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA).[6] The horizontal grid spacing of this data set is 3 arc-seconds, or about 90 m. The source of land cover data was the 28.5 m resolution GeoCover LC data set generated by MDA Federal from Landsat Thematic Mapper imagery. The NDVI and sea-surface temperature data were derived from the satellite-based Advanced Very High Resolution Radiometer (AVHRR), and have a spatial resolution of 1 km.[7] All geophysical data sets employed by the models are projected and resampled to the spatial resolution of the simulations, as needed.

Computer and Storage Systems

The MesoMap system requires a very powerful set of computers and storage systems to produce detailed wind resource maps in a reasonable amount of time. To meet this need AWS Truepower has created a distributed processing network consisting of 80 Intel Dual Quad Core Xeon processors (640 total cores) and 100 terabytes of hard disk storage. Since each day simulated by a processor is entirely independent of other days, a project can be run on this system up to 640 times faster than would be possible with any single processor.

The Mapping Process

The MesoMap system creates a wind resource map in several steps. First, the MASS model simulates weather conditions over 366 days selected from a 15-year period. The days are chosen through a stratified random sampling scheme so that each month and season is represented equally in the sample; only the year is randomized. Each simulation generates wind and other weather variables (including temperature, pressure, moisture, turbulent kinetic energy, and heat flux) in three dimensions throughout the model domain, and the information is stored at hourly intervals. When the runs are finished, the results are summarized in files, which are then input into the WindMap program for the final mapping stage. The two main products are usually (1) color-coded maps of mean wind speed and power density at various heights above ground and (2) data files containing wind speed and direction frequency distribution parameters.

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[5] Robert Kistler et al., The NCEP/NCAR Reanalysis, Bulletin of the American Meteorological Society (2001).

[6] For more information, see http://www2.jpl.nasa.gov/srtm/.

[7] See http://edcwww.cr.usgs.gov/products/landcover/glcc.html.

Once completed, the maps and data are compared with available land and ocean surface wind measurements, and are adjusted if significant discrepancies are observed. The best source of validation data is tall towers instrumented for wind energy assessment. Standard meteorological stations, which are generally on much shorter towers, can also be used, along with remotely sensed data such as satellite-based sea-surface winds. The validation is usually carried out in the following steps:

1. Station locations are verified and adjusted, if necessary, by comparing the quoted elevations and station descriptions against the elevation and land cover maps. Where there are obvious errors in position, the stations are moved to the nearest point with the correct elevation and surface characteristics.
2. The observed mean speed and power are adjusted to the long-term climate norm and then extrapolated to the map height using the power law. Often, for the tall towers, little or no extrapolation is needed. Where multi-level data are available, the observed mean wind shear exponent is used. Where measurements were taken at a single height, the wind shear is estimated from available information concerning the station location and surroundings.
3. The predicted and measured/extrapolated speeds are compared, and the map bias (map speed minus measured/extrapolated speed) is calculated for each point. If there are enough towers, the mean bias and standard deviation of the biases is calculated. (It is important to note that the bias and standard deviation may reflect errors in the data as well as in the maps.)
4. The maps are adjusted to reduce observed discrepancies. The goal of the adjustment is not to eliminate errors at every point where there is a measurement, but to address patterns of bias affecting substantial regions.

Accuracy

The MesoMap system has been validated according to the method described above using data from well over 3000 stations worldwide. The map error margin (the standard error of the distribution of biases between the predicted and observed mean speeds) typically ranges from 0.2 m/s to 0.8 m/s at a mean speed at a height of 80 m. Because the errors tend to be only weakly related to mean wind speed, they tend to be larger, in percentage terms, at low wind resource sites than at high wind resource sites.

The following factors can affect the accuracy of the wind maps:

- Finite grid scale of the simulations
- Errors in assumed surface properties such as roughness
- Errors in the topographical and land cover databases
- Limitations of the models employed

The finite grid scale of the simulations results in a smoothing of terrain features such as mountains and valleys. For example, a mountain ridge that is 2000 m above sea level may appear to the model to be only 1600 m high. Where the flow is forced over the terrain, this smoothing can result in an underestimation of the mean wind speed or power at the ridge top. Where the mountains block the flow, on the other hand, the smoothing can result in an overestimation of the resource, as the model understates the blocking effect. The problem of finite grid scale can be solved by increasing the spatial resolution of the simulations, but at a cost in computer processing and storage.

While topographic data are usually reliable, errors in the size and location of terrain features nonetheless occur from time to time. Errors in the land cover data are more common, and usually result from the misclassification of aerial or satellite imagery. Wherever possible, AWS Truepower uses the most accurate and detailed land cover databases.

Assuming the land cover types are correctly identified, there remains uncertainty in the surface properties that should be assigned to each type, and especially the vegetation height and roughness. A forest, for example, may consist of a variety of trees of varying heights and density, leaf characteristics, and other features affecting surface roughness. An area designated as cropland may be devoid of trees, or it may be broken up into fields separated by windbreaks. Uncertainties such as these can be resolved only by visiting the region and verifying firsthand the land cover data. However this is not practical when (as in most MesoMap projects) the area being mapped is large.

Last, limitations in the model equations, and especially in the parameterization of sub-grid-scale meteorological phenomena such as turbulence and convection, can produce significant errors in simulated wind speeds. Such errors are an unavoidable consequence of the state of the art of numerical weather prediction.

RESULTS

The standard MesoMap configuration was used in creating the Wind Resource Atlas of Vietnam. The mesoscale model, MASS, was run with a horizontal grid spacing of 2.5 km. The microscale model, WindMap, was run with a horizontal grid spacing of 200 m. SRTM was the source of topographic data, and GeoCover LC provided the land cover data. In converting from land cover to surface roughness, the roughness length values shown in Table 1 were assumed. (We believe these values to be typical of conditions in Vietnam; however, the true roughness could vary a great deal within each class.) Mean wind speed maps were created for three heights above ground: 60 m, 80 m, and 100 m. These maps are presented in Figures 2, 3, and 4. In addition, data files of estimated mean wind speed by month and estimated frequency and energy by direction were generated.

Table 1. Land-cover types and corresponding surface roughness length values employed in creating the Wind Resource Atlas of Vietnam.

Land Cover Type	Surface Roughness Length (m)
Coniferous Forest	2.25
Deciduous Forest	1.875
Shrub land/Transitional	0.375
Cropland/Grassland	0.15 & 0.10
Wetland	0.20 & 1.125
Bare rock/Soil	0.05
Built-up Environment	0.75
Water	0.001

Wind Resource Maps

As in most tropical and sub-tropical regions, the prevailing synoptic-scale winds in Vietnam are relatively weak. The dominant influences are the summer and winter monsoons, which are created by differences in temperature between the Asian land mass and the surrounding oceans – sea breezes on a vast scale.

The summer monsoon induces a counter-clockwise circulation around southern and eastern Asia, resulting in generally southerly and westerly winds in Vietnam. The winter monsoon creates the opposite circulation, resulting in mainly northerly and easterly winds.

Because of the weak ambient winds, the most promising areas for wind development in Vietnam occur where the terrain concentrates the wind flow. Several such areas are visible in the maps in Figures 2, 3 and 4. Starting in the south, the relatively good wind resource along exposed coastal points of south-central Vietnam, especially between Ho Chi Minh City and Khanh Hoa, is due mainly to deflection of the monsoon winds, especially in summer, around the Southeast Asian landmass, and secondarily to localized sea breezes. The mean wind speed at 80 m height at these points is predicted to reach 6.5 m/s to 7.0 m/s. Farther south there is another area of better-than-average winds (5.0 m/s to 6.0 m/s) along the coast near Can Tho. The third area of significant interest is the highlands west of Binh Dinh along the Dac Lac and Gia Lai provincial border, where channeling through a broad mountain gap is expected to result in mean wind speeds of 6.0 m/s to 6.5 m/s.

Moving north, relatively windy areas are mainly confined to the coast, notably near Quang Binh and southeast of Ha Noi. These are due mainly to sea breezes. In addition, the forcing of winds over the mountains along the Laotian border in central Vietnam is predicted to produce relatively good winds along the ridgelines.

Aside from these areas, the maps indicate that most of the rest of Vietnam experiences relatively low wind speeds ranging from less than 3.0 m/s to 5.0 m/s at 80 m.

Comparison with Observations

AWS Truepower validated the wind maps by comparing the predicted speeds with data from 9 towers, including 8 tall towers instrumented for wind energy assessment (three from the MOIT wind resource assessment project and five from a private source) and one standard meteorological station which passed our quality-control tests. The results are shown in Table 2. In summary, the predicted mean wind speeds at 80 m are on average 0.24 m/s, or 4%, less than the observed means projected to the same height; the standard deviation of the biases is 0.84 m/s, or 13% of the projected observed mean.

These deviations are at the high end of the normal range for the MesoMap system. This could reflect problems with either the simulations or the observations, or both. Among other issues, it was not possible to verify the exact locations, instrument heights, or data quality of the five proprietary towers. Furthermore, because of a lack of suitable long-term reference measurements, the mean speed estimates are based on the period of measurement, which may not reflect long-term conditions. In addition, the relative paucity of high-quality meteorological observations and the region’s complex terrain and active weather systems make this region challenging for numerical weather simulations.

The error margin of the wind resource maps is difficult to estimate with confidence given the fairly small number of comparison stations. Based on the limited findings and experience in other regions, we estimate the standard error to be 0.8 m/s.

Table 2. Comparison of mean predicted and observed wind speeds at nine stations in Vietnam.

Name	Latitude	Longitude	Station Type	Top Sensor Height (m)	Observed 80m Wind Speed (m/s)	Predicted 80m Wind Speed (m/s)	Bias
Phan Rang	11.4316	108.9851	Tall Tower	60.1	6.46	7.06	0.60
Phan Thiet	11.0760	108.4517	Tall Tower	60.1	6.27	6.79	0.52
Play Cu	13.7511	107.9941	Tall Tower	60.1	6.32	6.50	0.18
Proprietary			Tall Tower	60			-1.67
Proprietary			Tall Tower	60			0.18
Proprietary			Tall Tower	60			-1.41
Proprietary			Tall Tower	60			-0.32
Proprietary			Tall Tower	40			-0.62
Tan Son Hoa			Airport	10	3.54	3.94	0.40
Average					**6.31**	**6.07**	**-0.24**
Standard Deviation							**0.84**

Guidelines for Interpreting and Using the Maps

Users of the Wind Resource Atlas of Vietnam should be aware that the mean wind speed at any particular location may depart substantially from the predicted values, especially where the elevation, exposure, or surface roughness differs from that assumed by the model, or where the model scale is inadequate to resolve significant features of the terrain. This section provides guidelines for interpreting and adjusting the wind speed estimates in the maps.

1. The maps assume that all locations are free of obstacles that could disrupt or impede the wind flow. “Obstacle” does not apply to trees if they are common to the landscape, since their effects are already accounted for in the predicted speed. However, a large outcropping of rock or a building would pose an obstacle, as would a nearby shelterbelt of trees or a building in an otherwise open landscape. As a rule of thumb, the effect of such obstacles extends to a height of about twice the obstacle height and to a distance downwind of 10-20 times the obstacle height.
2. Generally speaking, points that lie above the average elevation within a grid cell will be somewhat windier than points that lie below it. A rule of thumb is that every 100 m increase in elevation will raise the mean speed by about 0.5-1 m/s. This formula is most applicable to small, isolated hills or ridges in flat terrain.
3. The mean wind speed can be affected by the surface roughness up to several kilometers away. If the roughness is much lower than that assumed by the model, the mean wind speed may be higher, and vice-versa.

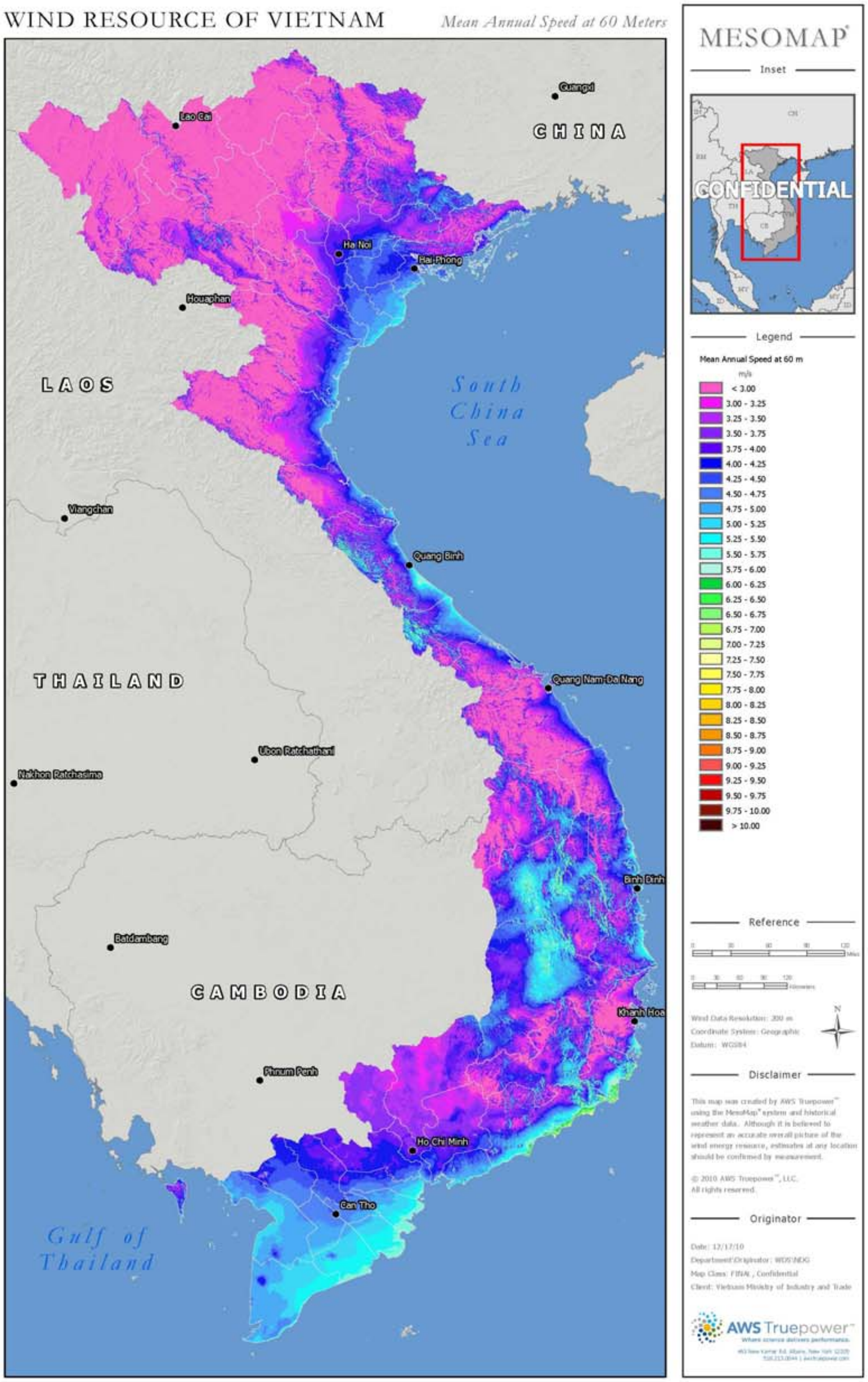

Figure 2. Wind speed map of Vietnam for a height of 60 m.

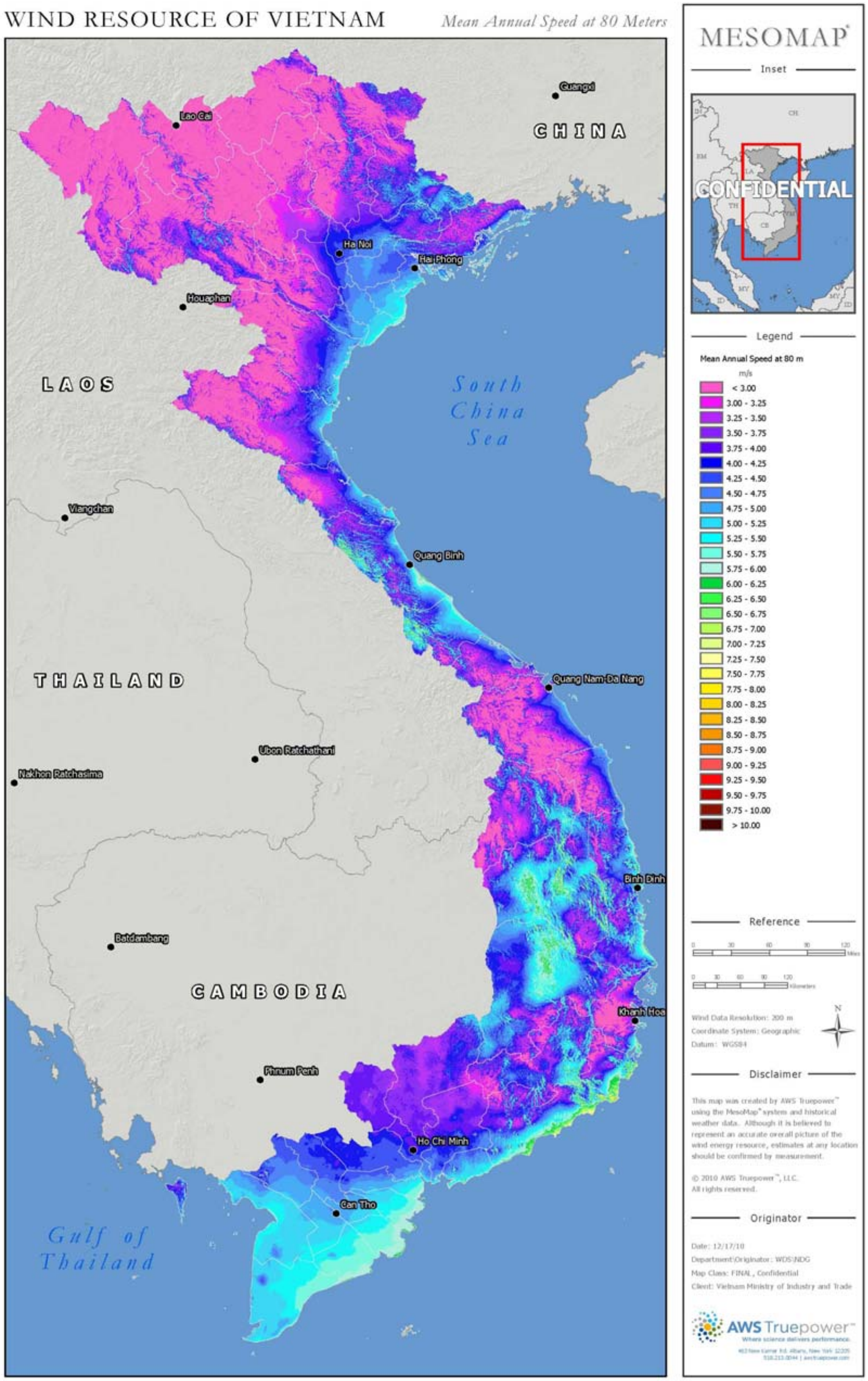

Figure 3. Wind speed map of Vietnam for a height of 80 m.

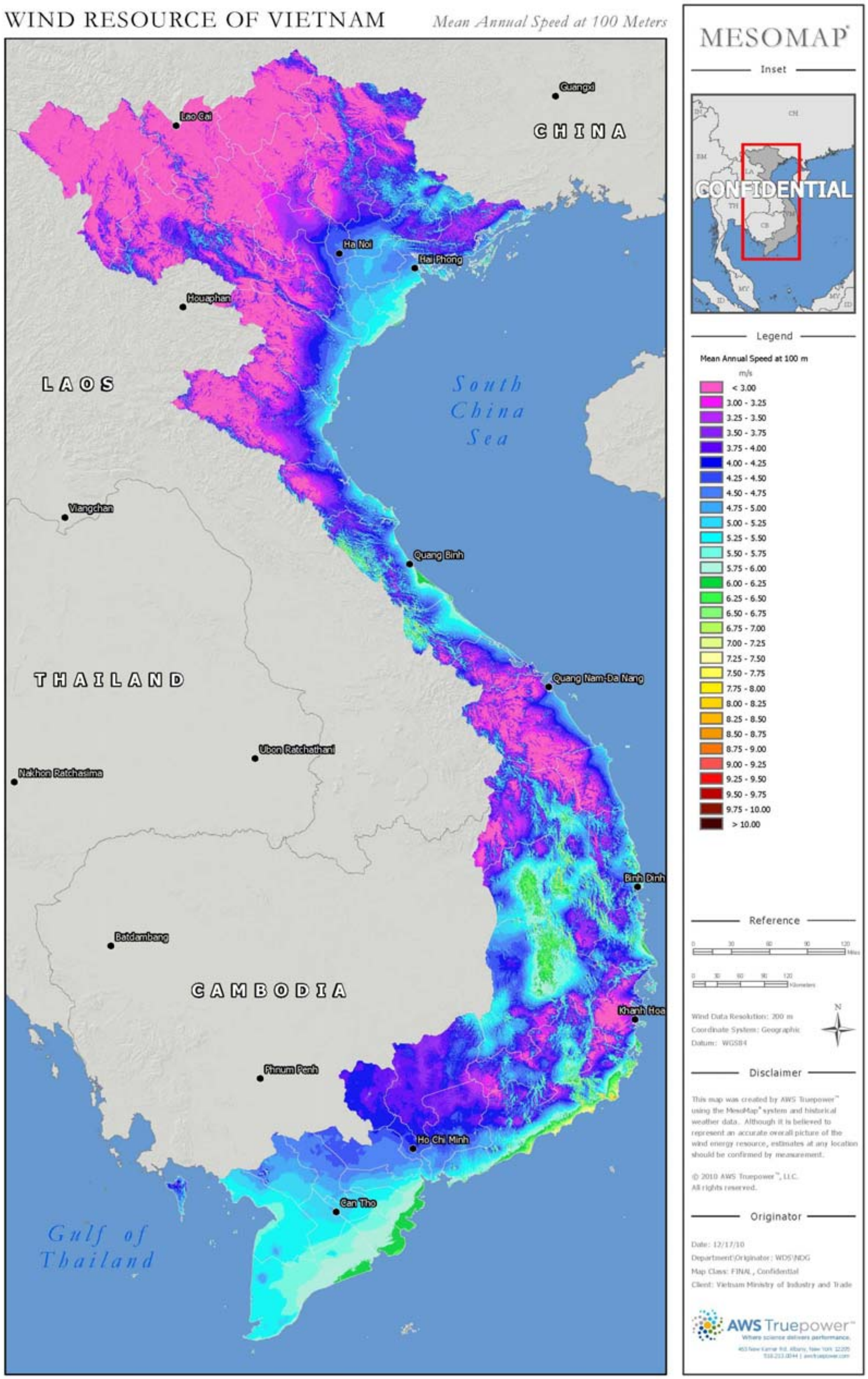

Figure 4. Wind speed map of Vietnam for a height of 100 m.

WIND RESOURCE POTENTIAL OF VIETNAM

Based on the new wind resource maps, AWS Truepower updated its estimates of the developable wind resource potential of Vietnam. This was done in several steps. First, areas likely to be unsuitable for development were identified. These included areas with slopes exceeding 20%, internationally and nationally protected parks and nature preserves, wetlands, urban areas, and watercourses and water bodies. The remaining areas were grouped into categories according to predicted mean wind speed at 80 m height. The developable area within each speed threshold category was calculated, and from this the potential wind plant capacity was estimated assuming a mean density of 10 megawatts (MW) per square kilometer.

The results are given in Table 3. It should be stressed that these values represent, at best, a very approximate, high-level estimate of the developable potential. Among other things, economic viability, local siting constraints, community concerns, locations of transmission lines and transmission capacity, and the influence of topography on wind turbine density have not been considered.

Table 3. Developable wind energy potential based on the Wind Resource Atlas of Vietnam. Areas deemed unlikely to be developed as described in the text have been excluded. All other areas are assumed fully available for wind development, with an average density of 10 MW/km^2.

Mean Speed at 80 m Height (m/s)	Estimated Developable Land Area (km^2)	Percentage of Developable Land	Approximate Megawatt Potential
< 4	95,916	45.7%	959,161
4–5	70,868	33.8%	708,678
5–6	40,473	19.3%	404,732
6–7	2,435	1.2%	24,351
7–8	220	0.1%	2,202
8– 9	20	0.01%	200
> 9	1	0.00%	10
TOTAL	209,933	100.00%	2,099,333

VIETNAM *WINDEXPLORER®*

The Wind Resource Atlas of Vietnam is available through an internet-accessible portal called the Vietnam *windExplorer*. This tool allows the users to:

- Browse wind speed maps at heights of 60 m, 80 m, and 100 m above ground level at a horizontal grid resolution of 200 m
- View latitude, longitude, mean wind speed, mean wind power density, Weibull *A* and *k* parameters, elevation and roughness for a point on the map when a location is clicked
- View charts of mean wind speed by month and frequency by direction when a location is clicked

The site is administered by MOIT and will be maintained by AWS Truepower for three years. The following screenshots illustrate the functionality of the *windExplorer*.

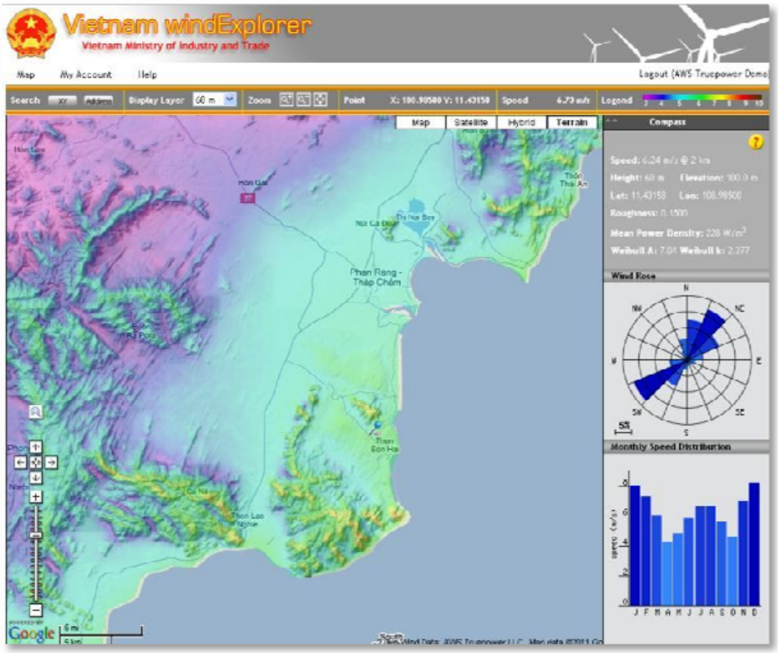

Figure 5. User interface for Vietnam *windExplorer* illustrating wind resource map, wind rose, and monthly distribution.

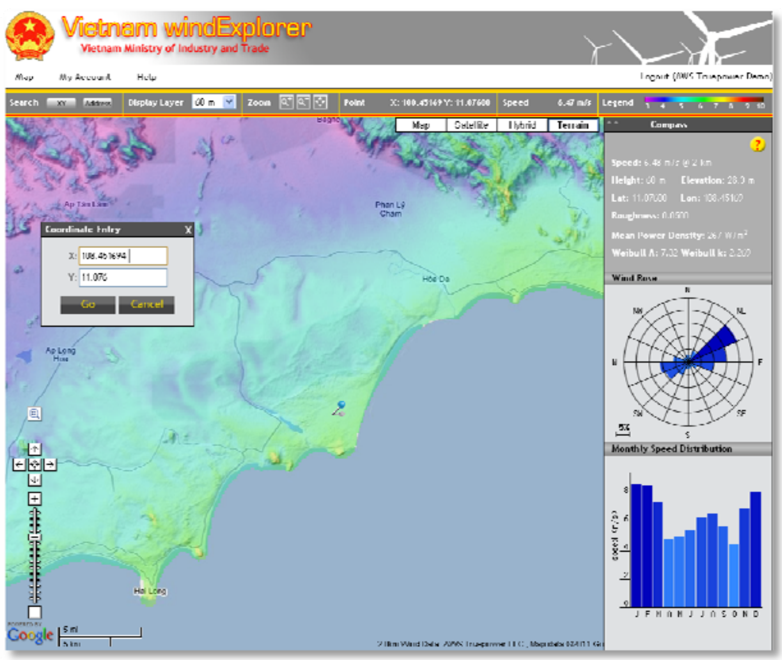

Figure 6. User interface for Vietnam *windExplorer* illustrating coordinate entry functionality.

CONCLUSIONS AND RECOMMENDATIONS

Under contract to MOIT and with the support of the World Bank, AWS Truepower has updated the wind resource assessment of Vietnam using its MesoMap system at a spatial resolution of 200 m and at heights suitable for modern, utility-scale wind turbines. The results support the previous finding that the Wind Energy Resource Atlas of Southeast Asia (2001) overestimated wind resources in Vietnam. However, the windy lands analysis performed for the present study suggests that Vietnam remains an attractive region for wind energy development. A leading area of interest is the south-central coast. Mountain gaps between Laos and Vietnam as well as other coastal areas remain subjects of interest. The new Wind Resource Atlas of Vietnam has been made accessible through the Vietnam *windExplorer* portal, which will be administered by MOIT and will be served by AWS Truepower for three years. This should be valuable tool for wind project developers, government agencies, non-governmental organizations, and others considering opportunities for wind energy development in Vietnam.

The accuracy of the wind resource maps could be improved through continued data gathering and analysis. AWS Truepower recommends a new meteorological data gathering campaign to supplement the recently concluded MOIT wind resource assessment project. Monitoring should be focused in areas of potential strategic importance for wind energy development, and especially in regions that have not been previously monitored as part of the MOIT program. As with all wind resource assessment campaigns, international protocols concerning instrumentation, tower height, data collection, and data validation should be followed. Once at least a year of data has been taken, the new measurements may be used to adjust the Wind Resource Atlas of Vietnam either in whole or in part. This should increase confidence in the maps and lead to lower uncertainty.