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Numerical Wind Energy Atlas for Canada

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Introduction

A national map of wind resources is a prerequisite to consider the possibility of greater utilization of wind energy. In Canada, up to recently, the only wind resource map available for the whole country was generated by the interpolation of the major wind stations (10-year 1967-1976) observations at 10 m elevation (Walmsley and Morris, 1992). This map, based on a limited set of observations, does not have enough resolution to be useful for the wind industry. The growing need for the assessment of Canadian wind potential incited the Environment Canada to develop the Wind Energy Simulation Toolkit (WEST). This tool was recently used to create the Canadian Wind Energy Atlas. Its first version was released in October 2004 and is publicly available at http://www.windatlas.ca.

Atlas generation

The statistical-dynamical downscaling method (Frey-Buness et al., 1995) was applied to produce the wind atlas. The method consists of using large scale long term atmospheric data and their statistical properties to run a mesoscale model and then post-process its output in order to get a small scale picture of atmospheric motion.

a. Wind climate classification

The 3D representation of atmospheric state available every six hours at 2.5 degree resolution over the globe, known as NCEP/NCAR reanalysis data (Kalnay et al., 1996), was chosen as data base. The elements of the data base were classified (Frank et al., 2001) using three parameters: the geostrophic wind speed and direction at 0 m and the sign of 0-1500 m geostrophic wind shear. This way 432 bins called climate states were defined. Each element of the long time series (every 6 hours for 43 years from 1958 until 2000) of the geostrophic wind vector at 0 m from the data base was attributed to a particular climate state. For each data base grid point, the classification procedure allowed determining the climate states that occurred during the analyzed period and the number of their realizations which defined their frequency of occurrence. This information was necessary to initialize the mesoscale model and to do the post-processing.

b. Mesoscale simulations

The simulations were performed with the Mesoscale Compressible Community (MC2) model (Benoit et al., 1997). The Polar Stereographic grid with 5 km resolution at latitude 60 N was chosen. This grid was split into 65 partially overlapping domains of 175 by 175 points each to cover the whole Canadian territory. There were 28 unevenly distributed vertical levels with the two lowest model levels for wind calculations at 50 and 150 m. The center of each domain was associated with the nearest grid point of the NCEP/NCAR global data base. Due to the classification procedure this point was characterized by a specific set of climate states and their frequency of occurrence. For each climate state a simulation with the MC2 model was performed, downscaling this way the climate states to the model resolution. The simplified physics scheme without radiation, condensation or diurnal cycle was used in order to accelerate model convergence to the final state. The time step was 120 seconds and there was a nine hour adaptation period for the initial flow to the surface geophysical properties. Once the simulations finished, which took about 50,000 hours of central processing unit time on an Environment Canada supercomputer (about 65x300 simulations of about 2.5 hours duration each), the results were ready for post-processing.

c. Statistical post-processing

For each domain the entire set of model outputs was combined using the frequency of occurrence of the climate states simulated as their weight. This gave a set of 2D data at model resolution characterizing wind potential of the domain: mean wind speed and power and their standard deviation, frequency distribution of wind by sector and by speed class, mean wind power frequency and cumulative frequency distribution. Statistical post-processing prepared data to be used by a microscale model such as MS-Micro of Environment Canada (Walmsley et al., 1986) or WAsP of the Riso Laboratory of Denmark (Troen and Petersen, 1989) to refine the wind flow near complex surfaces.

Conclusion

Canada is the first large-area country in the world to have a comprehensive numerical wind atlas. As can be inferred from the preliminary results, Canada has an important wind potential. Province ranking, based on the 50 m above ground mean wind speed averaged over each province territory multiplied by the area of the territory, gives Nunavut the first place, followed by Quebec and the Northwest Territories. The average value of mean wind speed is highest for Newfoundland (8.1 m/s), followed by Prince Edward Island (7.0 m/s) and Quebec (6.4 m/s).

Future plans

As primary statistics, currently available on the Atlas Web site, have discontinuities at the domain interfaces the secondary and tertiary ones will be provided soon. The secondary level of statistics will consist in merging primary level results, and then re-splitting them to the individual domains. The tertiary level will start with the aggregation of simulation results, then the post-processing will be done over the whole territory, not as now over each domain separately, and the results will be split to individual domains. An elaborate validation process is a must, and will be soon undertaken. The ongoing work of porting the WEST system to Windows XP Pro will allow further enhancing of the Atlas to 1 km or hundreds of meters by the private sector. This will give an additional tool for the wind energy industry.

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