

Mesoscale Model Description

Appendix A - Mesoscale modelling

1. Purpose of the Mesoscale Time Series

The Mesoscale time series is provided to assist the customer in better understanding the long term climatology of a specific location. The mesoscale time series contains hourly values of modelled wind speed, wind direction, temperature and density derived from a mesoscale model simulation performed by Vestas. The time series is to be used in combination with on-site observational data, to estimate of the long term variability of the wind resource. The time series should not be directly used for power production estimates or as a representation the absolute value of the wind resource at the site. More information on the mesoscale model used to generate the time series can be found in the following section.

Vestas does not assume any responsibilities for the values contained in the time series and any calculations or assumptions that may be derived from them.

2. Mesoscale Model Simulation

Vestas' Mesoscale simulations are performed by the WRF model, modified by Vestas for optimal performance with respect to wind energy.

The WRF model is a commonly used, and scientifically well documented model which has been developed by the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), the National Center for Environmental Prediction (NCEP), the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma and the Federal Aviation Administration (FAA).

The advantage of the WRF model is the description of atmospheric phenomena between the global scales covered by global weather models (macro and synoptic scales) and the microscale phenomena, resolved by very detailed models, like CFD models. A good understanding of Mesoscale atmospheric processes is crucial in the process of mapping wind speeds and other meteorological key drivers for the wind power potential in a geographical region. Mesoscale data is able to capture the general trends in the wind behaviour on all temporal scales relevant for the wind resource distribution. The WRF model forms the data basis of the SiteHunt® reports by providing detailed climate information on an hourly basis from January 2000 to present. The data is utilized to create maps and statistics illustrating spatial and temporal variability in wind speed and other key drivers of the wind energy production. This can be used to identify areas where the wind resource may be suitable for wind power plants.

A nested grid layout enables capturing the effects of synoptic weather events on the wind resource, the most energetic mesoscale motions, and local climate conditions by simulating the effect of local terrain and local scale atmospheric circulations, all in one consistent model setup. The WRF model is initialized every 48 hours using data from the Global Forecast System (GFS) Analysis with boundary conditions updated every 6 hours. Since January 2000, the National Center for Environmental Prediction (NCEP) has maintained the GFS databases, which provide gridded analysis datasets by assimilating observations from satellite, airborne data, and ground-based instruments on horizontal grid of 1° by 1° at 6 hour intervals.

The WRF model is run with 62 vertical levels on a stretched vertical grid suitable for wind resource assessment. To ensure the boundary layer winds are effectively modelled, 17 of these vertical levels are located within the lowest kilometre above the surface. Additional information on the model physics and dynamics are listed below in Table 1 and

Table 2. For creating the long term time series normally the geographically closest model grid point is used, but sometimes the choice is performed manually using the topographically representative model grid point to improve the correlation between the mesoscale modelled and local measurement data. For SiteHunt®, various downscaling approaches are applied to ensure appropriate refinement of relevant phenomena for wind resources and risks assessment.

Parameterization	Scheme	Description
Microphysics	WRF Single Moment 5-class scheme	Mixed phases processes with supercooled water
Longwave Radiation	Rapid Radiative Transfer Model	An accurate scheme using look-up tables for efficiency. Accounts for multiple bands, trace gases, and microphysics species
Shortwave Radiation	Dudhia	Simple downward integration allowing efficiently for clouds and clear-sky absorption and scattering.
Surface Layer	Eta Similarity	Based on Monin-Obukhov with Zilitinkevich thermal roughness length and standard similarity functions from look-up tables
Land Surface	Noah Land Surface Model	Prognostic state of all relevant surface variables; MODIS land-use database.
Planetary Boundary Layer	Mellor-Yamada-Janjic (MYJ)	One-dimensional prognostic turbulent kinetic energy scheme with local vertical mixing
Cumulus	Kain-Fritsch	Deep and shallow convection sub-grid scheme using a mass flux approach with downdrafts and CAPE removal time scale.

Table 1: Physics parameterizations used in the WRF simulation.

Options	Scheme	Description
Diffusion	Simple Diffusion	Gradients are simply taken along coordinate surfaces
Eddy Coefficient (K) Option	Eddy Coefficient (K)	K for horizontal diffusion is diagnosed exclusively from horizontal deformation. The vertical diffusion is done by the PBL scheme.
Damping	Upper Damping	A Rayleigh relaxation layer is added at the model top to control reflection from the upper boundary
Time Integration	Runge-Kutta 3 rd order	Smaller time steps for acoustic and gravity-wave modes; variable time step capability
Advection	5th order horizontal advection schemes and 3 rd order vertical advection scheme.	Positive definite advection of moisture and scalars

Table 2: Dynamical options used in the WRF simulation.

3. Meteorological and topographic input data

The General Forecast System (GFS) is a global numerical weather prediction model that provides forecast data for up to 16 days ahead. It is recognized as one of the best computer weather prediction models currently available. The model is used in daily operational weather forecasting around the world. Additionally, the GFS global analysis is widely used in the WRF community worldwide and is thus validated on a regular basis by a number of independent sources. It is important to note that there have been several updates to the GFS model over the last 10 years. The observations assimilated into the model are also continuously updated. However, this is standard for all types of global weather forecasting systems and must be taken into account regardless of the kind of input data used to force the mesoscale model. All changes to the GFS model since 1999 have been thoroughly documented and can be easily traced. More information can be found at (http://wwwt.emc.ncep.noaa.gov/gmb/STATS/html/model_changes.html)

Terrain topography and the values of constant, climatological parameters (e.g. deep soil temperature) are provided from the MODIS global database with down to around 1km resolution (30"). (https://lpdaac.usgs.gov/lpdaac/products/modis_overview)

References

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, M. G. Duda, X.-Y. Huang, W. Wang, and J. G. Powers, 2008: A description of the Advanced Research WRF version 3. NCAR Technical Note NCAR/TN475 + STR. URL http://www.mmm.ucar.edu/wrf/users/docs/arw_v3.pdf

NCEP(GFS - FNL) - National Center for Environmental Prediction Global Forecast System (Final) global gridded analysis archive - 2000 to Present. URL: <http://www.ncep.noaa.gov/>
