AUSTRIAN WIND ATLAS AND WIND POTENTIAL ANALYSIS

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Summary

Within the project 'Austrian Wind Atlas and Wind Potential Analysis', a novel hybrid dynamical/geo-statistical modelling approach for near surface wind has been applied to calculate the theoretic wind potential of the Austrian territory: In a first step, an available climate database for a 10 km grid spacing has been further downscaled to 2 km over the Austrian territory by operating MM5 in dynamic initialisation mode. This dynamic initialisation mode has added value due to bias reduction and improvements of the frequency distribution of wind speed. In a second step, wind speeds from MM5 have been geo-statistically downscaled to 100m grid spacing and implicitly error-corrected. This interpolation part virtually has removed the remaining overall bias at the ingested observation stations and additionally reduced the spread of the biases. As a result of this hybrid dynamical/geo-statistical model, frequency distributions with 100 m grid spacing are available.
Based on the resulting theoretical wind resources, estimations regarding the realisable wind potentials have been performed by means of GIS modelling. This model not only considers spatial constraints, but also the crucial technical and economic criteria of wind energy. In order to allow the user to manually select/alter the values for those constraints, a WebGIS based software framework has been developed. Based on the manual settings and the wind distribution for each 100 x 100 m raster cell, the GIS application dynamically calculates the realisable energy potential. The results are illustrated on district level in terms of possible annual energy yield per year [GWh/year].
Both, the results regarding the theoretical wind potential and the WebGIS application for the estimation of the realisable wind potential will be presented to the public at the beginning of 2011 and subsequently be freely accessible on the project webpage www.windatlas.at.

1. Introduction

Due to the diversity of the Austrian orography, the Austrian wind resources are characterised by a large variety of local winds, low level jets and supra-regional wind streams. Because of interaction of the different wind systems, an accurate simulation of the theoretical wind conditions is neither possible through stand-alone application of dynamic models nor through geo-statistical techniques.
Previous estimations on the realisable wind potential in Austria indicate a large range from 3 TWh to 20 TWh. However in most cases, only criteria of regional planning have been considered but other crucial parameter like technical development of turbine size and profitability have been neglected. This combined with the inaccurate wind resource estimations caused severe uncertainties in the results.
In order to overcome these shortcomings, the project "Austrian Wind Atlas and Wind Potential Analysis" (www.windatlas.at), funded by the Austrian "Climate- und Energy Fund", was initiated.
Aim of this study is on the one hand the development and testing of a new modelling approach in order to calculate a detailed wind resource map, which fits the reality as accurately as possible and, on the other hand, the subsequent comprehensive modelling of the wind potential that is realisable under alterable parameter settings.

2. Methodology

2.1 Theoretical Wind Resources
Due to the strong dependency of near surface wind on surface characteristics, accurate highly resolved wind climatologies in complex terrain are difficult to obtain. Earlier attempts in the European Alpine region were purely based on geo-statistical interpolation methods or dynamical fluid models. The accuracy of geo-statistical methods highly depends on the density and quality of wind observations while dynamical models are extremely time consuming and an appropriate horizontal resolution of 100 m is not achievable in long-term climate simulations.
During AuWiPot, a novel hybrid dynamical/geo-statistical modelling approach for near surface wind was developed *(1)* to provide error-corrected mean wind speeds and frequency distributions on the highly resolved grid (100 m horizontal grid spacing) in complex terrain.
This method consists of two downscaling steps, the dynamic PSU/NCAR model MM5 *(2)* and a geo-statistic method based on empirical experiences *(3).*
In the first step MM5 is applied to the reanalysis dataset ERA-40 *(4)* in multiple-nested model domains to successively increase the resolution of meteorological fields from 80 km x 120 km grid spacing (ERA-40) over 30 km x 30 km (Europe, domain A1, Fig .1) and 10 km x 10 km (Alpine

region, domain A2, Fig. 1) to 2 km x 2 km (Austrian territory, domain A3, Fig. 1). Thereby, the steps over 30 km and 10 km were conducted *(5)* during the Austrian regional climate modelling project reclip:more *(6)*. In the step to reach 2 km grid spacing MM5 was operated in dynamic initialization *(7)* mode.

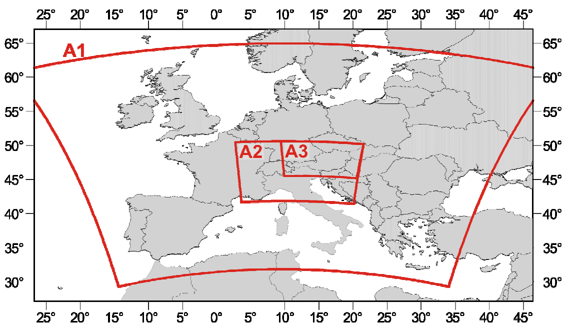

Fig. 1 Nested simulation domains of the dynamic model MM5 with 30 km (A1), 10 km (A2), and 2 km (A3) grid spacing.

From the MM5 output of domain A3 mean wind speeds as well as shape and scale parameters of the Weibull distribution were derived and geo-statistically downscaled to 100 m grid spacing. The wind speeds are re-gridded to the 100 m grid via bi-linear interpolation and modified by the domain-averaged vertical gradient of wind speed which was derived from A3 to get intermediate fields. Modifications of the wind speed in the 100 m grid due to spatially higher resolved land use characteristics is based on the CORINE land cover dataset *(8)*. Finally, these intermediate MM5 speeds are bias-corrected via the spatially interpolated relative error, which is derived from observational data and additionally smoothed by averaging. The smoothed topography in the MM5 model is not able to resolve terrain features like high ridges, canyons or narrow valleys as it is shown in Figure 2. Those terrain features have a strong impact on the flow of the wind so that additional corrections were applied based on terrain analysis.

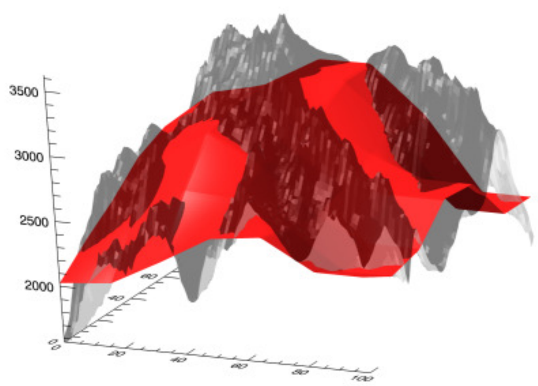

Fig. 2 Different topographies in the 2 km grid spaced MM5 model (red) and in the 100 m grid (grey).

The downscaling method was applied on the year 1999 for development purposes and on the period 1981 to 1990, representing current climate.
In order to judge the representativness of this period, trend analyses of observed long-term time series of selected (eleven reliable anemometer measurements with high quality) have been conducted and indicate that up to now annual wind speeds have not significantly changed in Austria since the 1980s (not shown). The same has been reported for Germany *(9)*. Even from analyses of proxy data (i.e., air pressure, temperature, precipitation, duration of sunshine, and cloudiness) a distinctive trend for near surface wind in the Alpine region cannot be derived *(10)*. Therefore, the period from 1981 to 1990 is assumed to represent current climate conditions well enough.

2.2 Realisable Wind Potential
In general, various and varying impacts influence the ability of utilizing wind power at a certain geographic location: Minimum distances to settlement structures need to be considered; terrain slope, protected areas and economic considerations are other crucial criteria for the ability of installing wind turbines. Since all these parameter are different for varying turbine sizes, a dynamic framework has been developed in order to allow the user a manual selection/change of those criteria. The framework follows a grid based approach considering a spatial resolution of 100 x 100m raster cells.
Depending on the selected turbine sizes, the individual constraints are evaluated and a decision for each single raster cells is generated regarding a possible installation at that location. The resulting layer represents the information, at which location which turbine size can be installed, on a 100 x 100 m resolution.
In a second step this decision layer is merged with the theoretical 3-dim wind potential, which is available as Weibull distribution (A and k parameter) for different heights above ground and for a grid resolution of 100 x 100m.
Merged with the assumption of a specific power curve [W/m^2], the selected turbine size and the required minimum distance in between the turbines, an annual energy yield will be evaluated.
In a final step, the annual Energy yield at a certain location is used for the estimation of the site-specific production costs]. In case the derived site-specific production costs are lower than the feed-in tariff [€Cent/kWh] selected by the user, those areas are excluded from the wind potential analysis.
After a validation with actual energy yields of existing wind farms, the modelled annual energy yields for the remaining locations are aggregated and presented as annual energy yield per year and administrative district [GWh/year*district].

3. Results

3.1 Theoretical Wind Resources
The final calculations on the theoretical wind potential are currently being performed and will

result in error-corrected mean wind speeds and frequency distributions on a highly resolved grid of 100 x 100 m on different levels between 50 and 130 m above ground.
An evaluation has been performed in Figure 3 and reveals that the MM5 model overestimates the mean wind speed at most of the measurement stations. With the statistical bias and terrain corrections an improvement in mean wind speed was achieved.

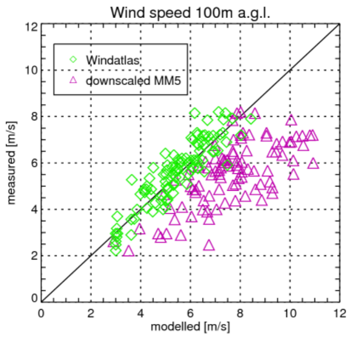

Fig. 3 Evaluation of the correction terms: Scatter plot of observed and modelled annual wind speeds at 176 observation stations. Intermediate MM5wind speeds (magenta) and the output of the combined dynamic/geo-statistic modelling approach (green) are shown.

3.2 Realisable Wind Potential
The WebGIS application for the estimation of the realisable wind potential will be available online. On a free internet platform the user has the possibility to choose technical, economical, environmental and spatial parameters via a scenario matrix (Fig. 4) and trigger an 'on-the-fly' calculation, which is based on those personal settings. The so calculated realisable wind energy potential is illustrated on district level.

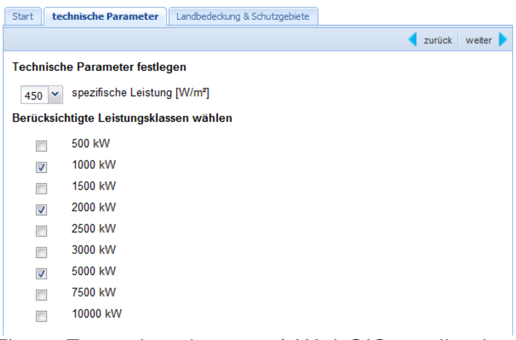

Fig. 4 Exemplary layout of WebGIS application with possibility to manually select the turbines sizes that shall be used for the calculation of the realizable energy yield.

3.3 Publication of results
Both, the results regarding the theoretical wind potential, as well as the dynamic WebGIS application for the estimation of the realizable wind potential, will be published at the end of the project (i.e. beginning of 2011).

4. Acknowledgment

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