THREE-DIMENSIONAL WIND FIELD CALCULATION ABOVE OROGRAPHIC COMPLEX TERRAIN IN SOUTHERN EUROPE

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Abstract

In the last few years the focus on more complex methods to model wind fields with three-dimensional nonlinear flow models increased. The advantages to model wind flows in complex terrain situations with those methods, compared to the up to now widely employed method WAsP, face a significant additional effort and a magnified computing time.

On the basis of seven wind measurements near the village Castronovo within the island of Sicily a comparative case study was performed showing the advantages and disadvantages of the flow models WindSim and WAsP.

1 General overview

The aim of the present study is to compare the ability of the 3-D nonlinear flow model WindSim and the linear flow model WAsP to predict the wind in an complex terrain area in central Sicily. In that area, seven measurements were available for the test. For this study, each measurement was taken as input for both flow models to compute the wind characteristics of each other measurement site and was compared with the real observations.

2 Description of the site

The examined area is situated southern of the village Vicari, to the west of the village Lercara Friddi and northern of the village Castronovo. The northern part in the area is characterized of a range of hills from North to South separating in the northern part in two foothills to Northwest/Northeast orographically structured strongly.

Coming to the south, this ridge meets the Sicilian watershed which directs east-west.

The mountains reach altitudes to over 1.000 meters. The area is structured orographically and mainly divided by draining river valleys and mountain chains from North to South. Erosion base is the only about 30 km apart situated coast of the Tyrrhenian Sea, corresponding deep cut the valleys in this area already with altitudes less than 300 m. a. s. l.

The area is indicated by a distinctive, Mediterranean climate. Essential weather features of this climatic zone are dry and hot summers as well as mild damp winters. The first is caused by the influence of the subtropical high pressure zone dominating in summer against, which the region gets into the area of the low pressure zone indicated by the west drift current of the moderate latitude with the moving of the climatic zones to the south in winter.

The wind system of the Italian peninsula is particularly the Tramontana are distinctive besides south till southwesters, of these north-east, from the Balkans and the Alps blow over the Adriatic Sea and the Apennine in the direction of the Tyrrhenian sea. In the southern part, this applies particularly to the island of Sicily; there is a dominating wind system of the Sirocco blowing of the south-southeast, from North Africa over the Mediterranean in the direction of the European continent. Furthermore has to be mentioned the Mistral blowing, parallel to the Italian west coast from the opposite direction to the northwest

The basic wind potential in the region is high, due to the considerable orographically dimensions, general statements are, however, almost impossible. Orographically favoured locations contain of good till excellent wind conditions whereas the wind decreases are drastically at disadvantaged sites.

3 Measurement database

In the area, measurements took place at altogether 7 points. These are the following measurements in detail:

- ST06: 19 m height, located on the northwest foothill in the northern part of the wind farm. For the main wind direction SSE (Sirocco) this is a typical lee-side location.
- ST08: 21 m height, located on the northeast foothill in the northern part of the wind farm.
- ST16: 21 m height, close to a mountaintop in the central part of the domain.
- CN17: 21 m height, located on a nearly perfect shaped cosine hill in the southern part of the domain, close to the watershed.
- CN18/22: Very close to each other, located on the watershed ridge in the Southwest of the domain. ST22 measures at 21 m, ST18, which has been installed later, in 20 m, 30 m and 40 m.
- CN 21: 20 m, 30 m and 40 m measurement, located on the watershed ridge between two mountains some 10 m higher than the measurement site.

Time rows of all measurements were provided on the part of the customer of this project. The quality of the provided data is without exception high. All wind measurements has been inspected and photographed by Mr. Dipl. Inf. Carsten Albrecht several times during the year 2004.

The measurement data has been automatically and manually inspected and filtered, identifying inconsistencies and missing data. Only the time period for which all measurements deliver plausible data has been taken for the study.

A period of about 4 month from September to December 2004 finally was available for the study.

4 Wind field modelling

4.1 Roughness

The found and described area situation is found in the carried out classification of the roughness.

The complete area is structured extremely simple, grassland, mixed almost find itself exclusive with arable land which only is interrupted by quite occasional villages and few, small pine groves. Altogether, the roughness is on low values.

The roughness has been manually digitized with WindPRO using topographical maps in the scale of 1:10.000 and 1:50.000.

4.2 Orography

As already described, the orographically dimensions are considerable and complex. The situation was already explained in section 2

Orography has been taken from the SRTM database for the whole domain, converted to height contour lines. This database has been manually corrected on the base of topographical maps 1:10.000 for the area covered by the micro model.

Around the met masts, the terrain has been taken by height calibrated GPS, concerning the altitudes and exact met mast positions as well as micro-orographic structures, nearby the masts that could not be derived from the topographical maps. During all studies performed by AL-PRO so far (e. g. [6], [7]) we experienced that this detailed terrain evaluation increases dramatically the quality of the results.

4.3 Obstacles

No considerable wind obstacles are in the complete site area.

4.4 WindSim modeling

A two-step modelling method was chosen. Both models have been set up with the WindSim interface of WindPRO.

At first the wind conditions for a macro model were determined with the following parameters:

Domain size:	60x60 km
Model height:	3.000 m
Grid spacing x-y:	400 m
Vertical nodes:	23, height distribution factor 0,1
Number of nodes:	524.423
Iterations:	500

The model therefore reached from coast to coast in North-South direction. Thus also the more remote, but the flow conditions just into larger height influencing structures are engaged.

A sophisticated micro model was nested into this model with the following parameters in a second step:

Domain size:	16x20 km
Model height:	2.500 m
Grid spacing x-y:	50 m
Vertical nodes:	20, height distribution factor 0,09
Number of nodes:	2.568.000
Iterations:	500

The domain size is still large, testing with smaller micro domains but denser horizontal grid spacing showed a dramatic decrease in the quality of the computed results. Similar effects have been observed by AL-PRO for all validation cases performed so far.

The results of the micro model were used for the further analyses. The computations have been done for a standard k-ε turbulence closure and a modified one, using different parameterisation. No significant changes in the results have been observed in the present case.

4.5 WAsP modelling

The established roughness and height database has been taken as input for the WAsP calculations without limitations.

Each wind measurement has been converted to sector wise Weibull parameters using the meteo object of WindPRO.

Computations have been made using the Statgen and WAsP interface modules of WindPRO.

5 Results

5.1 Wind Roses

The observed wind roses show strong modifications of the main wind directions from site to site. The measured wind rose is shown in red in the following figures. Each row furthermore shows the computed wind rose for each other stations using the input from the given station.

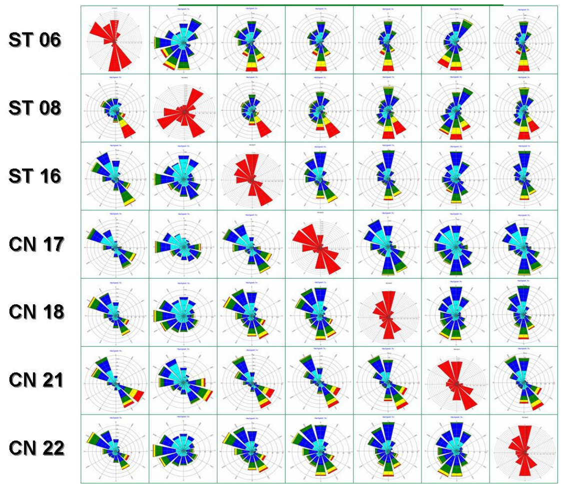


Figure: Wind roses computed by WAsP

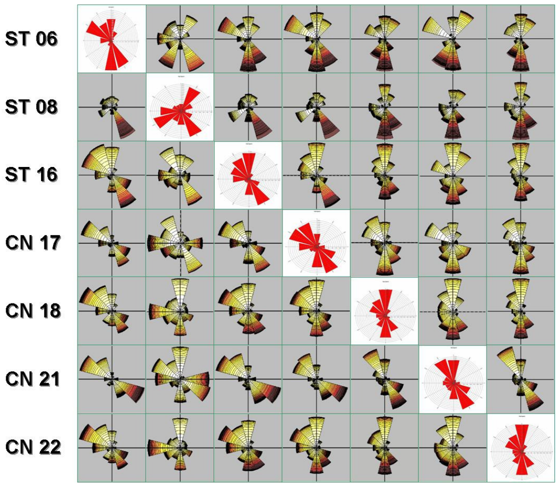


Figure: Wind roses computed by WindSim

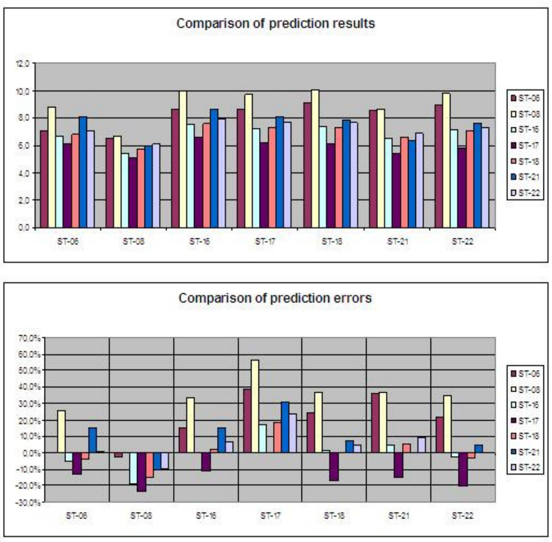
No quantitative analyse has been performed to examine the fit of the computations against real observations. At least, from visual inspection, it can be said that results from both models are not impressing. Obviously both calculation methods fail in computing wind turning effects inducted by the terrain in a satisfying way.

For WAsP, this is can be lead back to the limitations of a linear flow model due to flow modelling in complex terrain.

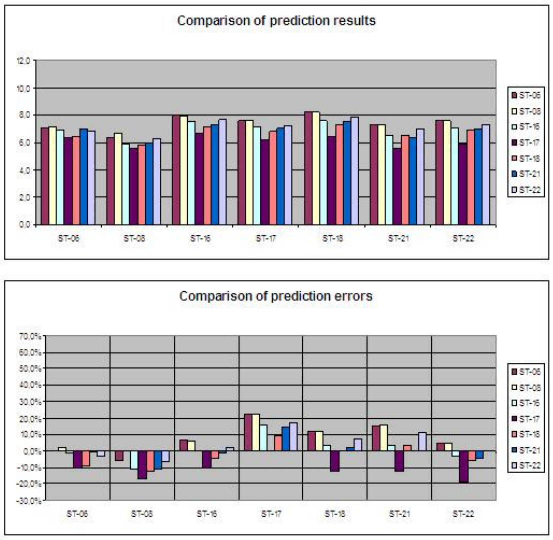
For WindSim a possible reason might be the unsatisfying approach in the software to transfer climatologies inside the model domain [5]. Possibly this method destroys a lot of the information established in the wind field computation before.

5.2 Wind speed

The wind speed at each station has been computed based on the data of each other. The results were compared against the real measurement. This analysis has been done both, the mean wind speed for all sectors as well as the sectorwise wind speeds.



Figures: Computations and computation errors WAsP



Figures: Computations and computation errors WindSim

The analyse clearly shows better results for WindSim here. This is underlined by analyzing the overall error and its standard deviation:

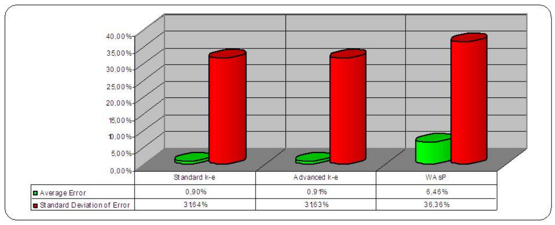


Figure: Error and standard deviation of error, stationwise

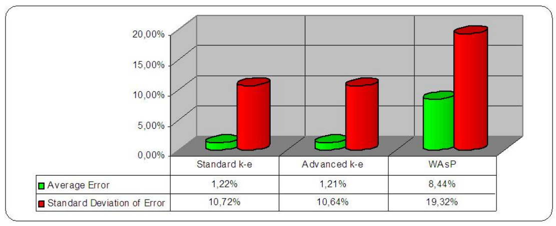


Figure: Error and standard deviation of error, sectorwise

The results show that uncertainty nearly can be halved regarding the mean wind speed using WindSim in this case. Taking into account that obviously both methods are unable to reproduce the behaviour of ST17, which is located in a very special and extreme terrain situation, as described, the quality of results for both flow models improve significantly. Except this station, WindSim is very well able to reproduce observed wind speeds in the domain.

5.3 Vertical profiles wind speed

This evaluation could only be performed on the data of station CN18 as there were problems with the wind vane of CN 21. The wind speed at 20 m and 30 m was computed using the input of 40 m

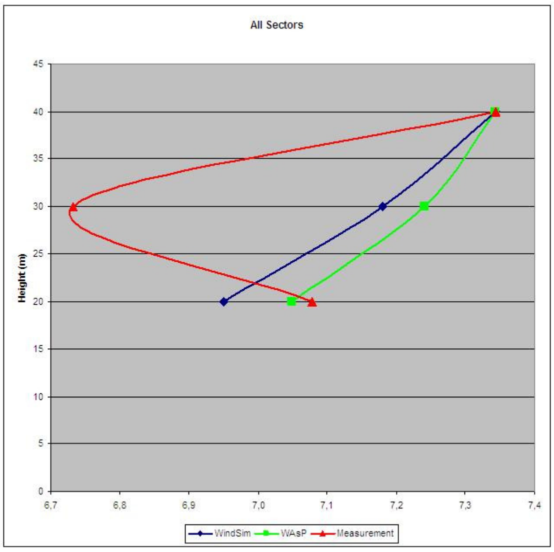


Figure: Vertical profiles CN18

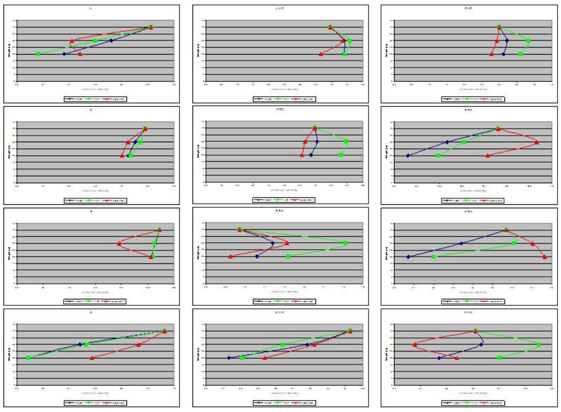


Figure: Vertical profiles sectorwise, CN18

Both models fail to compute the behaviour of the measurement in 30 m height regarding the cumulated wind speed for all sectors. At the same time, both models give quite similar results. For 20 m, WAsP is quite close to reality while WindSim under predicts a little bit.

Looking at the sectorwise results, things get different. WindSim is able to reproduce the profiles in a nice way in certain sectors, WAsP in others; while for some cases both models are close to each other – but far away from reality. To quantify this, again the sectorwise overall error and it's standard deviation has been evaluated:

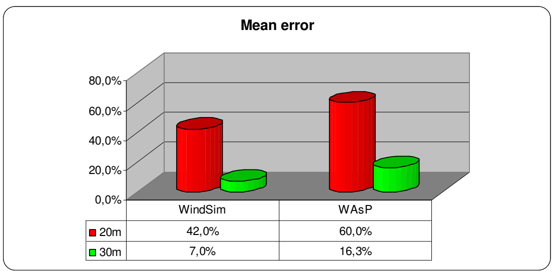


Figure: Prediction error for each height

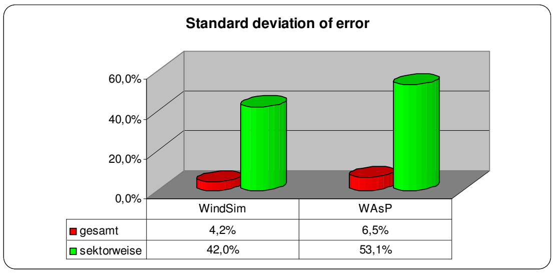


Figure: Standard deviation of Prediction error for each height

The first thing to observe is the tendency of both models to over predict the wind speed at lower height in the particular case. It is well known that WAsP is overestimating speedups properly in such a complex terrain situation. Obviously the use of WindSim is an improvement, while also with this model a tendency to over predict speedups can be observed.

Also regarding the standard deviation of errors WindSim shows a lightly better behaviour as WAsP. On the other hand, the improvement is not as significant as observed for the mean wind speed.

5.4 Vertical profiles k-parameter

Similar examinations as described in the previous section have been carried out regarding to the vertical profile of the k-Parameter of the underlying Weibull Distribution of the wind speed. Together with the wind speed, this parameter is the decisive one for the determination of the energy content in the wind.

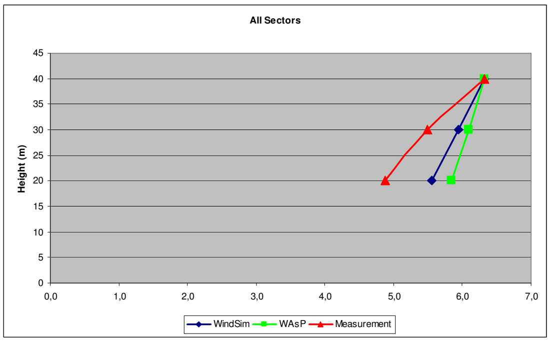


Figure: Vertical profiles k-Parameter CN18

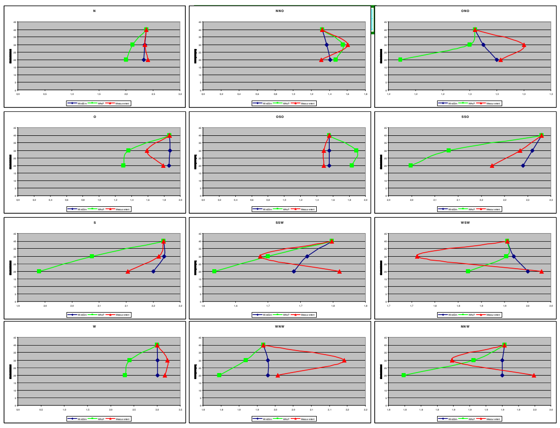


Figure: Vertical profiles k-Parameter sectorwise, CN18

As already can be seen from the figures, obviously WindSim is closer to reality regarding the k-Parameter compared with WAsP. This becomes clear especially when looking at the sectorwise results.

To quantify, again the total error and it's standard deviation has been evaluated.

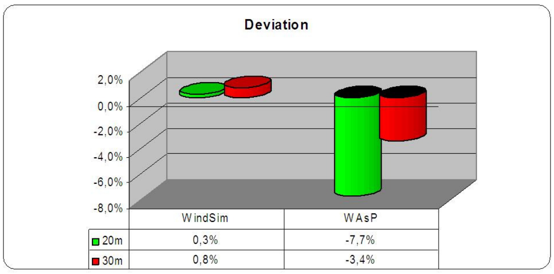


Figure: Prediction error for each height

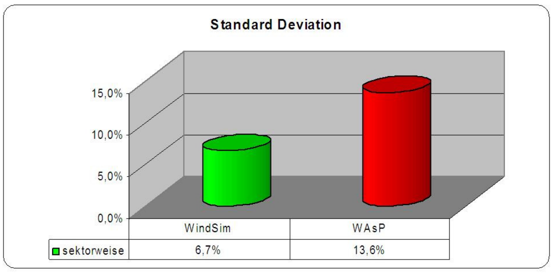


Figure: Standard deviation of Prediction error for each height

The results underline the observation that WindSim delivers clearly better results for this topic. Similar to the mean wind speed, the uncertainty could be halved by using WindSim

6 Conclusion

The evaluation showed quite different results of the ability of both flow models to reproduce the real situations.

Regarding wind roses, the results of both models could not satisfy. In the case of WindSim, improvements are possible; as a result of this study AL-PRO is actually developing an additional method to transfer time series data directly which should solve the problems with discretisation of tabular distribution representations. The results of this improvement are planned to be presented in an additional paper soon.

For the most important parameters in the regard of wind resource assessment which are the wind speed and the shape of the speed distribution WindSim clearly showed decisive advantages compared with WAsP. It has to be said, that this improvements only could be reached when the size even of the micro domain had been extended to the described size. Approaches with smaller domains lead to much worse results. The same can be said in the terrain modelling, only high precise determination of the terrain, especially close to the met tower's sites, gave good results – which is similar to the results of WAsP, also in other cases.

Credits

We have to thank in particular our customer Green Engineering & consulting s.r.l. and especially the owners Mrs. Christina and Mr. Francesco La Marca who were so kind to allow us to publish the measured data in the present way. Without that, this study would not have been possible.

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