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The Application of MCP Techniques and CFD Modelling for Wind Resource Assessment in a Mediterranean Island Context

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KEYWORDS

wind resources, MCP, CFD, Mediterranean, Maltese islands.

ABSTRACT

This paper presents salient results from an ongoing investigation into wind behaviour and resources characterisation on the central Mediterranean Maltese archipelago. The ultimate aim is to enable a more accurate determination of the potential for electrical wind power generation in the onshore and inshore marine environments. One area of this research is seeking to generate longer-term wind characteristics at selected locations. The strategy used involves a combination of field measurements at a number of onshore points and the use of Measure-Correlate-Predict (MCP) techniques in conjunction with Computational Fluid Dynamics (CFD) software. This current study will present selected results from the validation process underway to establish the performance of MCP and CFD in a sub-tropical island context.

INTRODUCTION

Interest in the prospects of wind power generation as a contributor to the central Mediterranean Maltese archipelago's 2020 renewable energy targets kick-started technical studies to explore the feasibility of installing wind farms in the onshore and offshore environments. Two of the three sites that have been shortlisted as possible wind farm development areas are onshore, while the third is offshore in the near-shore coastal zone [1]. The availability of wind measurements at, or close to these locations as well as the geophysical characteristics of this central Mediterranean island group make a case study on the operation and validation of Measure-Correlate-Predict (MCP) techniques and on the performance of commercially-available Computational Fluid Dynamics (CFD) software particularly relevant.

NOMENCLATURE

$\overline{U}$	[ms^{-1}]	average wind speed
N		number of observations
Δt	[minutes]	time interval
A	[ms^{-1}]	Weibull scale parameter
k		Weibull shape parameter
a.g.l.		above ground level
m.s.l.		mean sea level
DTM		digital terrain map
Easting	[m]	Cartesian coordinates on *x-axis*
Northing	[m]	Cartesian coordinates on *y-axis*
z	[m]	height above ground level

BACKGROUND

Notwithstanding the small size of the islands, some locations on the Maltese archipelago exhibit better wind characteristics than others; a feature that may be attributed to the undulating and often cluttered topography, to differences in terrain elevation above sea level and to the sites' relative exposure to the prevailing winds. This makes wind resource quantification somewhat demanding and challenging unless measurements are carried out. The emphasis on reaching accurate wind resource quantification stems from the fact that the power available in the wind is directly proportional to the cube of the wind speed. An under- or over-estimate of wind speed will result in a substantial difference in the available power density; a factor that will also be mirrored in subsequent wind turbine performance projections.

A wind monitoring campaign's ultimate aim is therefore to establish a candidate site's longer-term wind climate and to reduce the level of uncertainty of such mathematical projections. The minimum period for field measurements is of about 6 calendar months, although a longer data collection exercise of at least 12 calendar months will reduce the level of uncertainty [2]. Bias could also be introduced due to aspects such as seasonal or monthly variability [3].

Correlation between the candidate site data and data from other nearby stations that possess longer-term datasets is required to generate longer-term projections at the site of interest. This is necessary to transpose the candidate site's short-term wind behavior into timeframes that are representative of the operational lifetime of modern wind turbines i.e. of about 20 years. Even then, the candidate site's extrapolated long-term wind climate remains one of a historical nature, as it reflects what the wind behavior at the site of interest would have been like in the past. A basic premise is that this long-term historical climatological fingerprint would also reflect wind behavior in the future at a time when the wind turbines would be up and running. Field measurements in conjunction with MCPs are thus an industry recognised way of determining longer-term wind resources at a candidate location.

For prospective wind turbine installations in complex terrain the candidate site measurements do not necessarily reflect wind conditions within the wider area or region of interest as wind speeds, shear and turbulence could differ within a few hundred metres. This is where wind flow modelling software has a specific and useful role to fulfil. With the advent of commercial computational fluid dynamics (CFD) software, wind engineers have the capability of handling complex computations that solve the Navier Stokes equations. CFD can help as a precursor to site-specific field measurements and also allows for analysis of fluid flow at a micro-siting level.

PURPOSE OF STUDY

Ongoing research at the Institute for Sustainable Energy [4] and the Department of Mechanical Engineering [5] of the University of Malta is endeavouring to generate knowledge on wind resources and wind behaviour in the local context. The work currently underway may best be described by three inter-dependent, investigative initiatives as follows:

Duration of Field Measurements and the Impact on the Accuracy of Key Wind Parameters

A comparative two-way analysis was carried out between two local candidate sites where field measurements are in progress. This analysis was conducted to assess the behaviour of key wind parameters and to gauge the improvement in accuracy of results for ever-increasing duration of the field measurement campaign. The first parameter of interest is the wind speed. For a series of N wind speed observations U_i that are averaged over a defined time interval Δt, the average wind speed $\overline{U}$ may be found as follows [6]:

$$\overline{U} = \frac{1}{N}\sum_{i=1}^{N} U_i \qquad (1)$$

The Weibull distribution is a probability distribution that enables calculation of various parameters related to a location's wind climatology and also wind turbine performance estimates. This two parameter distribution may be defined [6] as follows with the probability of the wind speed U being given by:

$$p(U) = \left(\frac{k}{A}\right)\left(\frac{U}{A}\right)^{k-1} \exp\left[-\left(\frac{U}{A}\right)^{k}\right] \qquad (2)$$

where k is known as the shape factor and describes the shape of the distribution. A ($\mathrm{ms^{-1}}$) is known as the scale factor.

Duration of Concurrent Field Measurements and the Impact on the Accuracy of the MCP Results for Key Wind Parameters

The second initiative focused on establishing the deductive capabilities of two commonly-used MCP techniques applied in the local context. This section is important for future work as extended candidate site wind climatologies will eventually be used as inputs to wind flow modelling software. This will enable the generation of wider-ranging wind resource maps for the island group.

Using Field Measurements to Validate CFD Results

The CFD wind modelling software being used requires the modules to be calibrated against data captured from on-site measurements. This initiative therefore validated the results generated by CFD against site-specific results generated from the field studies.

These three research fields will serve as a stepping stone for future work that will focus on generating long-term climatologies by means of MCP. After this, the outputs will be used to 'calibrate' the CFD models to generate wind resource maps that reflect the longer term wind climate on a site-specific and regional basis. Key parameters, including wind speed and the two Weibull variables, will serve as indicators and as a means of qualitative performance assessment of the above-mentioned initiatives as applied in the local context.

METHODOLOGY

Collaboration between the Ministry for Resources and Rural Affairs of the Government of Malta [7] and the Institute for Sustainable Energy of the University of Malta resulted in a revitalised and more intensive wind monitoring programme at *Wied Rini* (Site A); a site perched high on the south west coast (see Figure 1).

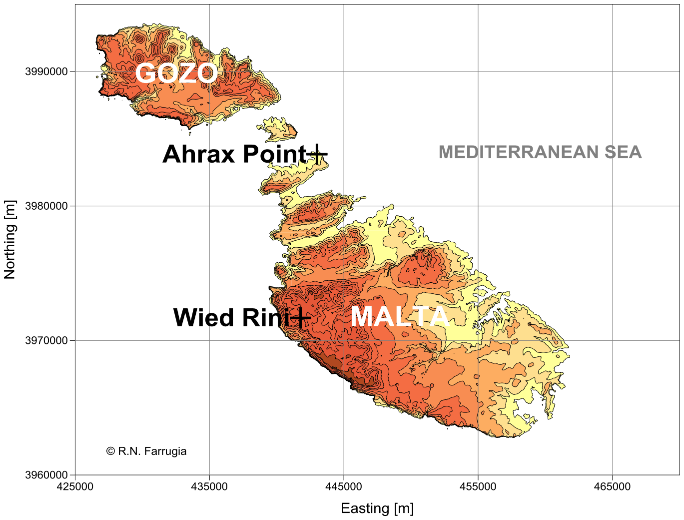


Figure 1: Map of the Maltese islands showing the position of the two candidate sites of *Wied Rini* (Site A) and *Ahrax Point* (Site B).

Measurements at Site A are now in their third year of continuous operation. The monitoring structure at Site A consists of a 45 metre telecommunication-type lattice tower rigged with various sensors at three main levels; namely 46, 23 and 10 metres above ground level (see Figure 2). The lattice-type mast is located at the neck of a shallow valley running towards the North West; the direction of the prevailing winds. The monitoring structure is a mere 1.6 km from the coastline where a steep coastal escarpment drops down to sea level. This report will focus solely on data from two of the mast's topmost sensors i.e. the anemometer and wind direction vane at 46 metres above ground level (also Figure 2). This site is characterised by higher than average wind speeds during the cooler period of the year between November and May with the remaining hotter months exhibiting lower than average wind speed values [8].

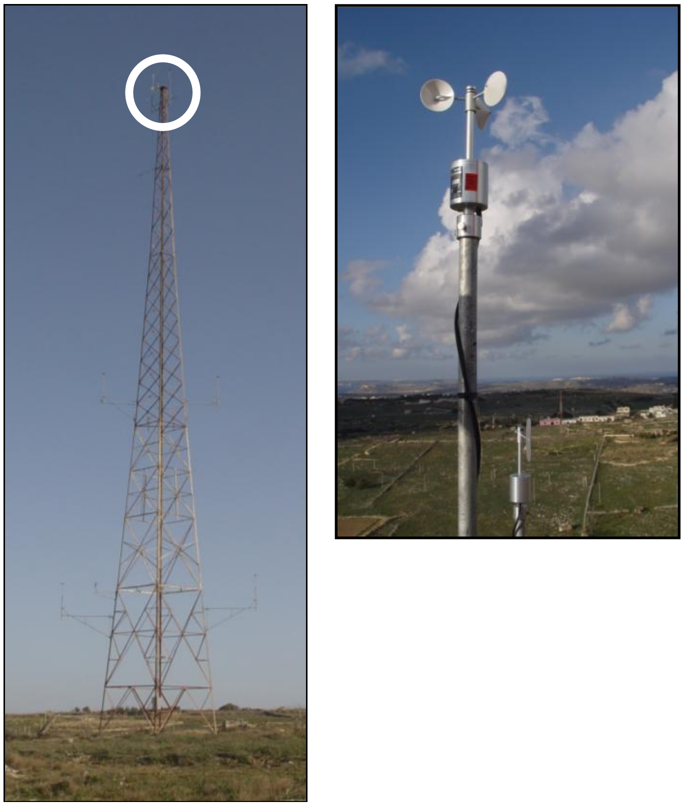


Figure 2: The left-hand photo shows the 45 metre former telecommunications tower being used for wind monitoring purposes at *Wied Rini* (Site A). The right hand photo shows a close-up of the anemometer and wind direction vane at the topmost mast level.

In late 2009, the Malta Resources Authority [9] embarked on a new wind measurement campaign at *Ahrax Point* (Site B). The mast at *Ahrax Point* consists of a tubular 80 metre mast guyed in four main directions and rigged with various sensors at different heights above the ground. The mast itself is installed on a small promontory that is less than 15 metres above mean sea level. The aim of the measurement programme at *Ahrax Point* is to investigate wind resources on an offshore reef known as *Is-Sikka l-Bajda* in the vicinity of the mast. The two sensors supplying wind data for this study are the mast's topmost anemometer (80 metres a.g.l.) and direction vane (78.5 metres a.g.l.). Figure 3 shows a photo of the mast and a close-up of typical wind speed and direction sensors used at this station. Some data loss occurred during the summer months of July and September 2010. The missing speed data was re-built from the Wied Rini 46 metre measurements using a sector-wise correlation. A linear regression (least-squares fit) was then applied to determine a transfer function for each of twelve sectors and the data gaps were subsequently filled with scaled *Wied Rini* values. Missing wind direction values were replaced directly with data from the *Wied Rini* 45 metre vane.

The main bodies of data used in this study consist of 12 concurrent months collected primarily during 2010 and 2011 from both sites. Twelve consecutive months covering typical hot and cold season months were selected in order to avoid bias due to seasonal variability.

Duration of Field Measurements and the Impact on the Accuracy of Key Wind Parameters

The impact of the duration of a wind measurement campaign has been assessed in works such as that of Ramsdell [3] and Wegely [10] amongst others. In this local study a simple comparative two-way analysis was carried out between the two candidate sites where field measurements are currently underway.

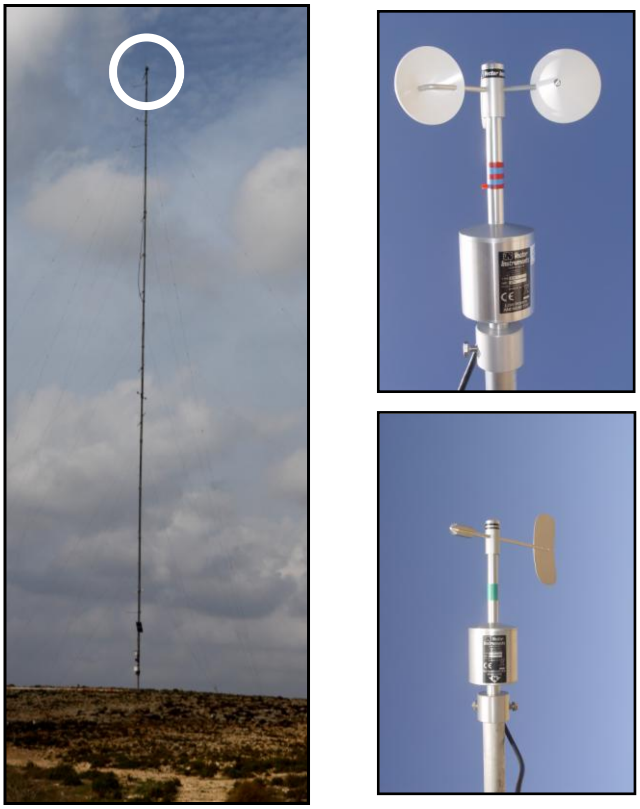


Figure 3: Photo showing the 80 metre mast as installed at *Ahrax Point*. The two topmost speed and direction sensors that are supplying data for this study are encircled. The close-up photos show typical sensors.

Method-wise, 1 month's worth of 10 minute average wind speed and wind direction data at each of the sites was analysed using EMD's WindPRO [11] software programme that includes a data analysis tool pack. The average wind speed $\overline{U}$ in ms^{-1} and the Weibull scale (A) and shape parameters k were calculated for the increasing monthly periods and for the full 12 month time frame.

The percentage differences between the key parameters for this first month of measurements were compared to the same parameters computed for the full 12-month duration. This comparison aimed to investigate whether one month of measurements represented sufficiently well the longer-term wind conditions. The process was repeated for the first and second months together, three consecutive months and so on, until the accuracy afforded by the accumulation of the full 12 months of measured data was attained. Figure 4 presents a schematic of this comparative methodology. This procedure was conducted for both sites independently and was dubbed Method 1 (M1).

Wind speeds at local sites exhibit marked seasonality with higher wind speeds in the colder months than in the hot summer months. Conducting the exercise with a time series that has a higher than average wind speed during the initial measurement period could distort the outcome of the analysis. Thus, the 12 month data set was split in half and rearranged with lower wind speed summer months now heading the hypothetical time series.

A repeat procedure of the analysis described above was conducted with an ever-increasing number of consecutive months being compared to the full 12-month time period. This method was called Method 2 (M2).

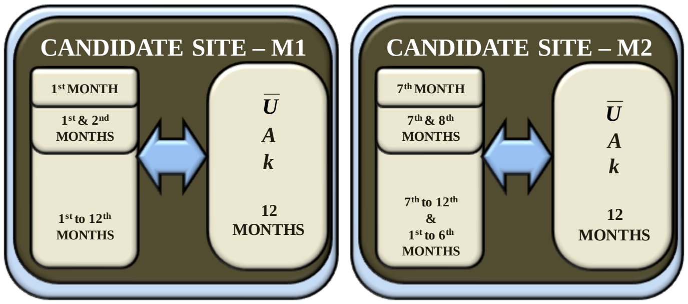


Figure 4: Methodologies used to assess the accuracy of short-term measurements at the candidate sites in representing longer-term wind conditions at the same locations.

Duration of Concurrent Field Measurements and the Impact on the Accuracy of the MCP Results for Key Wind Parameters

MCPs are generally used to generate a relationship between a new short-term '*candidate*' site and an established longer-term '*reference*' site over a concurrent measurement period. The resulting relationship exhibited during the concurrent measurement time frame is then used to upscale or downscale the reference site's longer-term wind climate. The end result would be a longer-term wind climate for the candidate site, or site of interest.

The first routine involved Site A being designated '*candidate*' site. One month of 10 minute average wind speed and direction data from the 46 metre level at Site A were verified. Meanwhile, Site B was assigned the role of '*reference*' site and 12 months of wind speed and wind direction 10 minute averages from the 80 / 78.5 metre sensors were organised. The WindPRO software's MCP module was then used to correlate the data between the two sites and the resulting 12 month 'extrapolated' wind climate, or meteorological object for Site A, was generated.

Two MCP methodologies were employed; the Linear Regression method and the Matrix method. Both techniques were used with default settings in order to test the efficacy of the results in their most straightforward and commonly-used form. Documentation on the operation and mathematical background of both Linear and Matrix MCP techniques may be sourced from the software's online information packs [11] and from other sources such as Anderson's 2004 comprehensive coverage of various MCP techniques [12].

The same procedure was then repeated with the candidate site (Site A) contributing two months of consecutive 10 minute averages, and therefore a longer concurrent period between the two locations. Once again the two MCP methods were used to generate a 12 month meteorological object that yielded the key monthly wind parameters for the candidate site. Runs with increasing duration of consecutive and concurrent measurements were carried out until the full 12 month period of measurements was attained for both sites (see Figure 5).

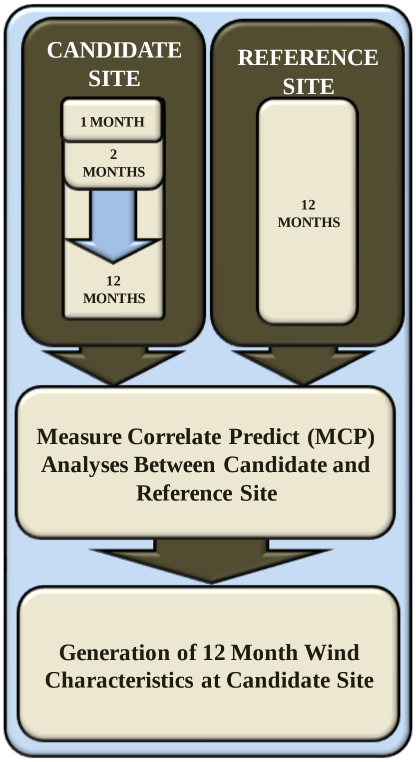


Figure 5: Schematic illustrating the methodology used to test the effects of increasing duration of concurrent measurement at a candidate site in a MCP process. In this case method M1 is shown.

The roles of Site A (as '*candidate*') and Site B (as '*reference*') were then reversed and the procedure repeated with increasing consecutive monthly timeframes. As in the previous case, starting off the analysis with months having higher and lower than average monthly means were called M1 and M2 respectively.

Using Field Measurements to Validate CFD Results

WindSim [13] is CFD software that has been specifically developed to model wind flow over various terrain types with the ultimate aims of generating wind resource maps and of quantifying wind turbine energy yield. The software solves the Reynolds Averaged Navier Stokes (RANS) equations through an iterative process with a solution being attained when full convergence of specific parameters is achieved.

3-D topography and surface roughness maps were prepared for the terrain model. These maps were generated using a combination of Golden Software [14] mapping software packages and are based on the Malta Environment and Planning Authority's 1:25,000 topographical maps for the islands [15].

Two distinct but inter-related terrain models were generated. The first was dubbed the macro model with a domain extending to cover the archipelago in its entirety and extending to also include a border of marine space around the islands. The extents of the digital terrain model (DTM) and of the grid established for the wind field CFD computations are listed in Table 1. A screenshot of the coverage of the macro model is illustrated in Figure 6. The height above the terrain was set to 1,500 metres to avoid blocking by high ground and the number of cells in the z-direction was set at 30 to force higher resolution close to the ground.

Table 1: Salient characteristics of the terrain extension and of the computational grid established for the macro model.

	x-extent [m]	*y-extent* [m]	Resolution [m]
DTM	52056.0	43038.0	135.0
	x-extent	*y-extent*	*z-extent*
Grid Spacing	135.0 m	135.0 m	Variable
No. of Cells	385	318	30

The '*Wind Fields*' module was run for 12 sectors with initial conditions set to the default boundary layer height of 500 metres and with a speed above that same layer of 10 ms^{-1}. Temperature was disregarded and the turbulence model used was the standard *k-epsilon* (k-ε) model inbuilt into the '*Wind Fields*' module. A segregated solver was used. The built-in convergence wizard was activated in sectors where convergence was difficult to achieve.

The results were then used as boundary conditions to the second model type, dubbed the micro model, in a technique called '*nesting*'. The nesting procedure allows for a more accurate definition of the model's inlet conditions. The micro model was designed to deal specifically with the region or domain encompassing both Sites A and B, thus enabling higher resolution at and around these points of interest. The more important '*Terrain*' model settings are listed in Table 2. The '*Wind Fields*' module was once again set for 12 sectors and all other parameters defined in the macro model description were retained.

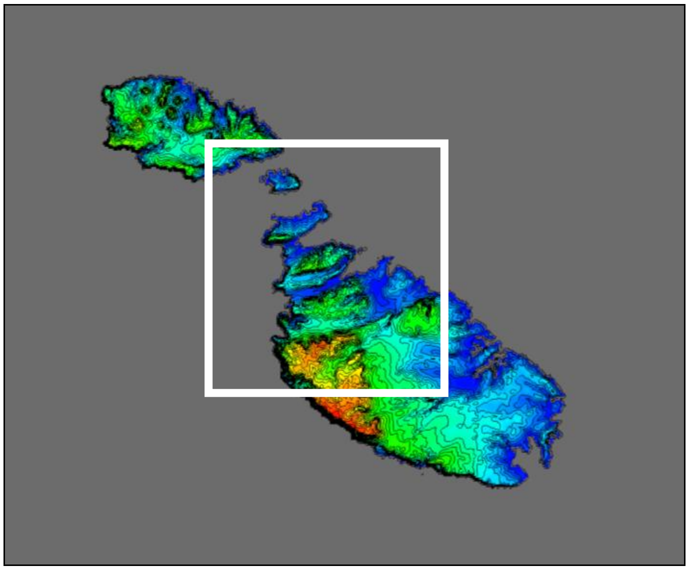


Figure 6: Topographic map showing the extent of the domain being used in the macro model CFD simulations. The inset square indicates the extent micro model domain.

Table 2: DTM and grid domain specifications as utilised in the micro model CFD runs.

	x-extent [m]	*y-extent* [m]	Resolution [m]
DTM	20115.0	20088.0	81.0
	x-extent	*y-extent*	*z-extent*
Grid Spacing	81.0 m	81.0 m	Variable
No. of Cells	248	248	30

In order to assess the performance of the CFD simulations in the local context, a methodology starting with single and then increasing number of consecutive months of measurement as climatology inputs to the micro model was used. This was repeated until the full 12 month duration of 10 minute average wind speed and wind direction values had been utilised.

Procedurally, a time-series consisting of one month of wind data from Site A was used to calibrate the CFD micro model at the point and appropriate height of measurement i.e. at 46 metres above ground level. A hypothetical turbine position was invoked at Site B and a 10 minute time series of wind speed and direction data subject to localised terrain and roughness conditions was generated for the same one month time frame. The results generated by the CFD modelling were subsequently compared to the corresponding results of the actual 80-metre measurements at Site B using the WindPRO data analysis facility. This process was then repeated with the duration of the climatological time series input at Site A being increased in monthly increments.

The same procedure was repeated yet again with Site A and Site B reversing roles i.e. with Site B's 80 metre measured data being used in ever increasing duration to calibrate the CFD model, extracting CFD simulated results for the height of interest at Site A (46 m) and then comparing to measured values. The climatological time series used in the above methodology commenced with a typically windy winter month (Method M1).

Once again, the original time series was parsed to generate a hypothetical data set that commenced instead with a low average wind speed period. The same process was repeated with increasing monthly steps of wind climatological input from Site A being used to calibrate the CFD model to project Site B's time series (Method M2). The roles of Site A and Site B were also once again switched.

It is worth mentioning that the simulations were carried out on a 'point-to-point' basis between the two sites and that while climatological values were representative of actual wind conditions at the point of measurement, the values resulting from the CFD runs are only indicative due to some differences between actual site coordinates and the resolution of the digitised and converted terrain map.

RESULTS

Duration of Field Measurements and the Impact on the Accuracy of Key Wind Parameters

The effect of increasing the duration of continuous measurements to represent longer-term wind parameters at the site of interest was tested on the two candidate sites as explained in the Methodology section. Figures 7a to 7c illustrate the percentage difference between the average monthly wind speeds $\overline{U}$ as well as the monthly Weibull parameters A and k for increasing consecutive months of measurement against the overall (12 month) period values for both locations. The percentage difference for the key parameters was defined as follows:

$$Percentage \cdot Difference = \frac{Predicted \cdot Value - Measured \cdot Value}{Measured \cdot Value} \times 100$$

The figures all show that increasing the duration of the measurement programme reduced the percentage difference between the predicted and measured values. In the case of the average wind speed (see Figure 7a), a large percentage difference would be expected for less than 8 to 9 consecutive months of measurement if a resource assessment programme is started in a typically windy month (M1 trends). For increasing number of consecutive months of monitoring, the difference dropped sequentially, although the values were always higher than the overall 12 month average up to the 8 month mark. With 8 months and over, the difference dropped to less than 5%. On the other hand, starting the measurements during a calmer month resulted in an underestimation of the 12 month average for monitoring time frames with duration of less than 8 consecutive months of measurement (see M2 trend lines). Beyond the 8 month point, the results were similar to those achieved using method M1.

In the case of the Weibull A parameter (Figure 7b), the same behaviour was exhibited with the number of consecutive months of measurement required to map the 12 month full-time-frame being around 9.

Observation of the variation of the Weibull k parameter (Figure 7c) does not lead to identification of any particular trends, although it is evident that fewer consecutive months of measurement resulted in larger differences.

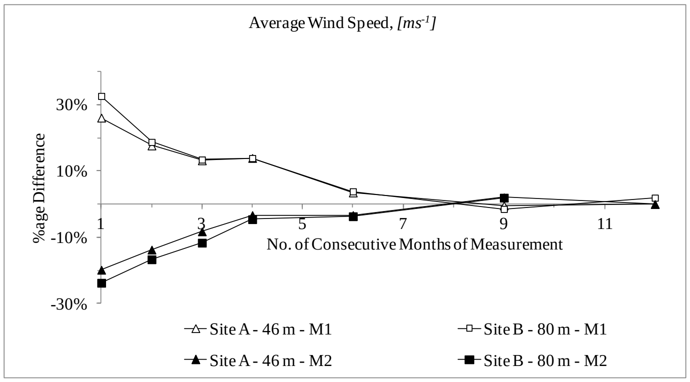


Figure 7a: Difference between $\overline{U}$ values for increasing consecutive months of measurement and the 12 month overall average wind speed value.

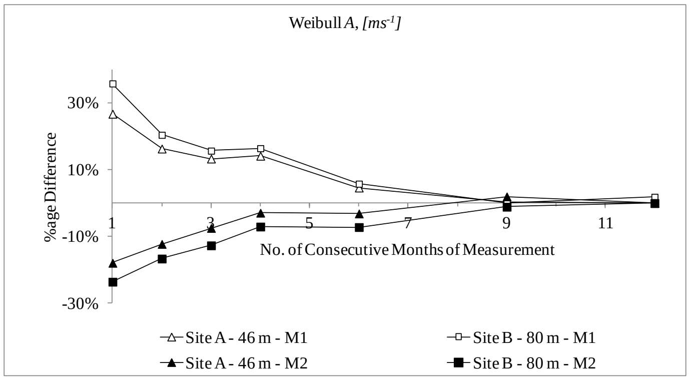


Figure 7b: Difference between the Weibull A values for increasing consecutive months of measurement and the 12 month overall scale parameter.

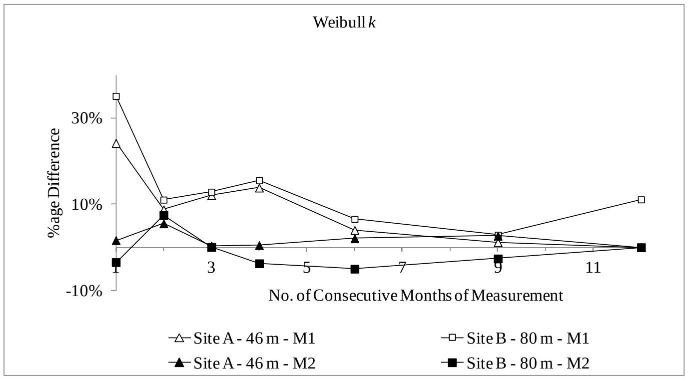
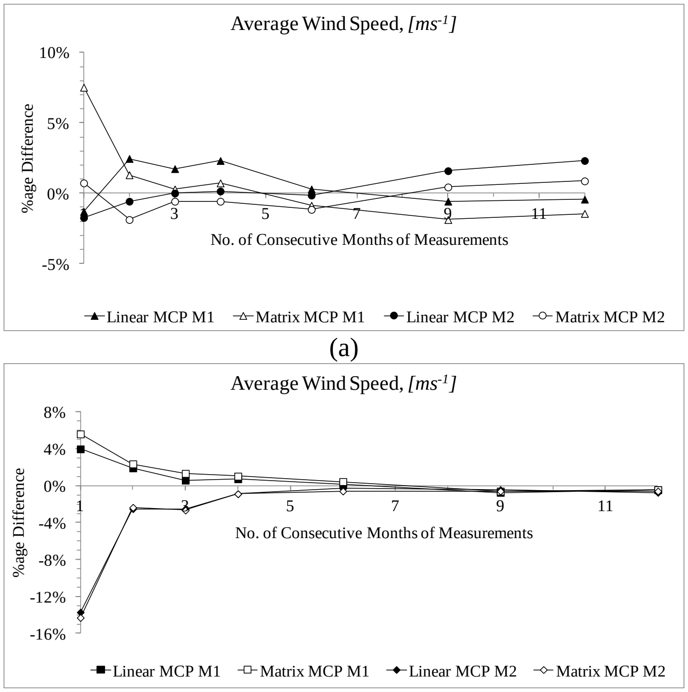


Figure 7c: Difference between the Weibull k values for increasing consecutive months of measurement and the 12 month overall shape parameter.

Duration of Concurrent Field Measurements and the Impact on the Accuracy of the MCP Results for Key Wind Parameters

The methodology described to test the effect of the duration of consecutive months of concurrent measurements on the MCP end results are illustrated in Figures 8, 9 and 10 for $\overline{U}$, *A* and *k* values at both sites. The percentage difference between MCP-generated and measured values were computed. Two different MCP techniques for both windy (M1) and calmer (M2) periods heading the datasets were conducted.

With Site B as reference, differences at Site A were rather erratic, particularly for periods of less than and up to about four months of concurrent measurement (Figure 8a). It is interesting to note that when Site A was used as reference, the resulting trends achieved for Site B tended to settle down with relatively minor differences beyond the consecutive and concurrent 4 month time-frame (Figure 8b). Beyond month 9, both MCP techniques marginally under-predicted the overall average wind speed.



(a)

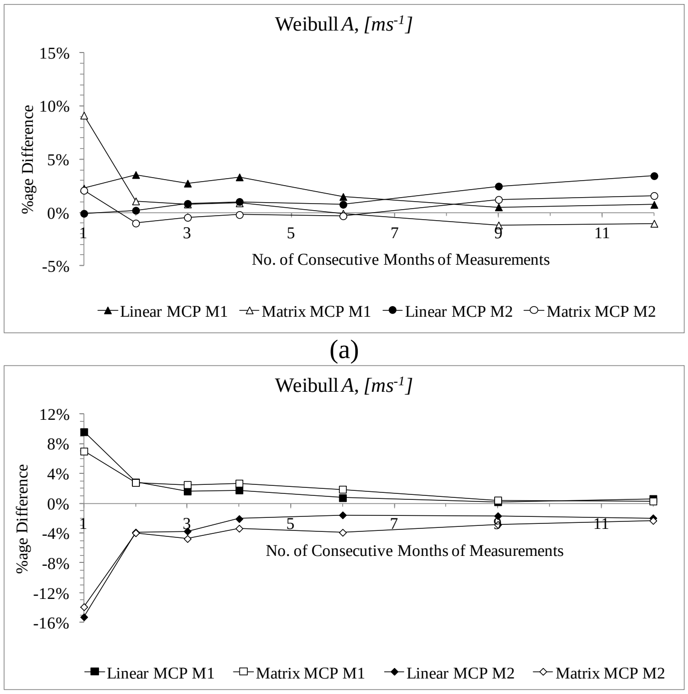
(b)

Figure 8: Percentage difference between the average wind speed for increasing number of consecutive and concurrent months of measurement and the average wind speed over the full term of measurement for Site A (a) and Site B (b) respectively.

The Weibull scale parameter *A* (in ms^{-1}) was also quite reliably represented when using MCP techniques on more than 4 concurrent months with Site A as reference (Figure 9b). This was to be expected as *A* is intrinsically related to the average wind speed. This latter aspect was re-affirmed by the similarities obtained between Figures 8 and 9. Another observation is that when using Site A as reference (Figure 9b), starting a monitoring campaign or data analysis during a calm period resulted in an under-estimate of the overall 12 month value in question. The opposite result is observed if the dataset was headed by a windier period.

Meanwhile, the values generated for the monthly Weibull shape parameter *k* once again seemed to be rather more difficult to predict (see Figure 10). Differences in excess of 10%; particularly when using Site B as reference and in the early stages of the measurement campaign (Figure 10a), were evident.

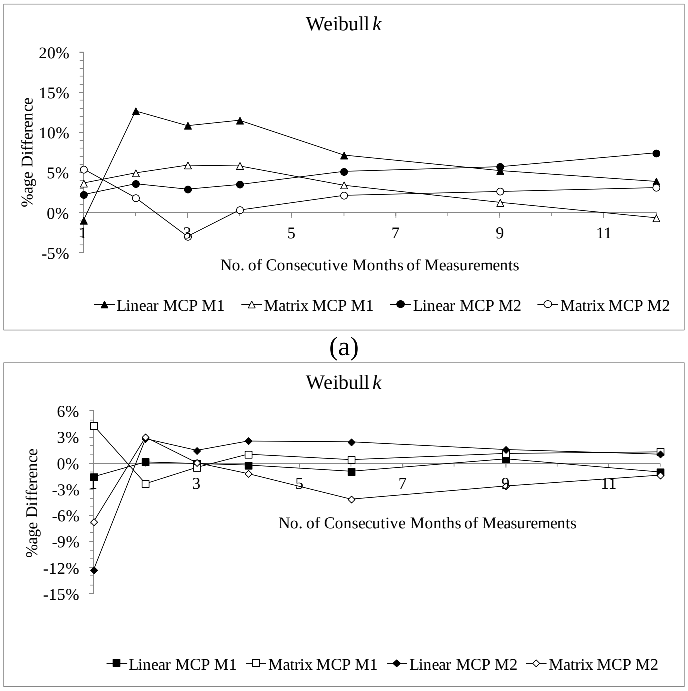
A general observation is that when used as reference, Site A's 46 metre data seemed to be more capable of representing wind conditions at 80 metres above ground level at Site B; particularly insofar as the average wind speed and Weibull scale parameter were concerned. This would seem to hold especially after a few consecutive, concurrent measurement months had been amassed. Generating conditions for Site A from Site B resulted in different and less defined trends; a feature that could be site or height specific. Unsteadiness of flow at Site A could be attributed to a more complex environment at this location hence leading to higher turbulence levels.



(a)

(b)

Figure 9: Percentage difference between the Weibull *A* parameter for increasing number of consecutive months of measurement and the scale parameter for the full term of measurement for Site A (a) and Site B (b) respectively.



(a)

(b)

Figure 10: Percentage difference between the Weibull *k* parameter for increasing number of consecutive months of measurement and *k* over the full term of measurement for Site A (a) and Site B (b) respectively using two different MCP methodologies.

Using Field Measurements to Validate CFD Results

Site A was first used to calibrate the CFD micro-model. The time series initially used a single typically windy month of 10 minute wind speed and direction averages. The wind climate at Site B was then generated for a height above ground level that was identical to the actual measurement height at the latter location. The average wind speed for the CFD-generated time series for that month (Site B) was then compared to the same parameter resulting from actual measured data. The percentage difference between the two was plotted (Figure 11). For Method 1 wind data, the percentage difference settled down to a consistent 4% value after about 4 consecutive months of measurement. It is also interesting to note that using measurements from Site A to calibrate the micro model resulted in an over-estimation of Site B wind resources.

The opposite applies when using Site B measurements to generate Site A resources. Starting off with a low wind speed month resulted in a more constant prediction from Site A to B and vice versa. The percentage difference settled down around the 4% mark after 4 to 5 consecutive measurement months. The over- and under-prediction phenomenon was however still in evidence.

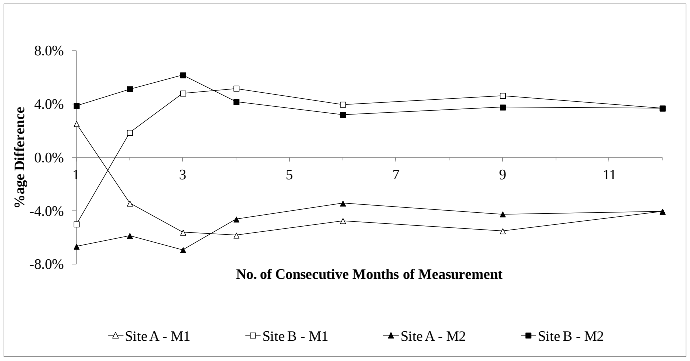


Figure 11: Percentage difference between the average wind speed calculated using CFD against the measured average for the same period (i.e. with increasing duration of measurements) using methods M1 and M2.

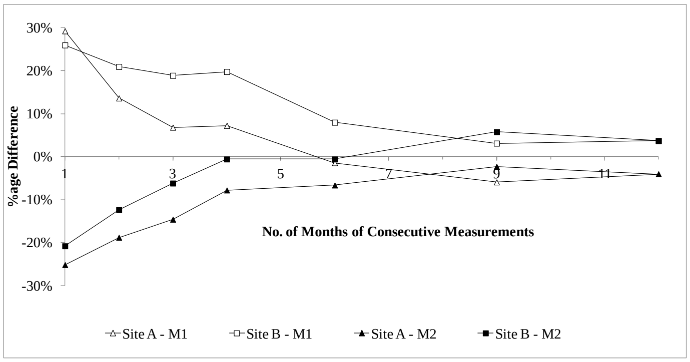


Figure 12: Percentage difference between the average wind speed for increasing monitoring programme duration using CFD calibrated with Site A and Site B measured data against the overall measured average for the 12-month time frame using methods M1 and M2.

Site A was once again used to calibrate the CFD micro-model with a time series initially consisting of a single typically windy month. The wind climate at Site B was then generated for the same timeframe and this was then compared to the measured overall 12 month value. Increasing durations of measured values from Site A were used to generate Site B's corresponding time series and so on. The roles of the two stations were then switched with Site B feeding data sets with increasing duration being then transposed to Site A. The generated parameters were again compared to the overall 12 month results. Figure 12 presents the percentage differences between the average wind speeds resulting from CFD against the overall measured average wind speed at the same site. Site A conditions were eventually under-estimated when using Site B's site-specific measured climatology as input to the CFD model. The opposite occurred when the sites were switched. Commencing a time series with a windy month, or with a comparatively low wind speed month to calibrate the CFD micro model, resulted in positive and negative differences. This holds especially during the earlier months of the measurement programme. Both methods converged to under-estimates for Site A and over-estimates for Site B. These results are consistent with results shown in Figure 11.

CONCLUSIONS

This paper presents some salient results from an ongoing and developing study that is envisaged to foster deeper knowledge on the regional and site-specific wind characteristics of a central Mediterranean island group. Wind data have been extracted from data sets being compiled at two locations in a coastal environment although the mast base elevation difference of the two sites is about 200 metres.

The importance of amassing a certain number of months of measurement to suitably characterise short-term wind conditions was confirmed by the results presented.

Results show the percentage differences decreasing against the 12 month overall parameters for increasing number of consecutive months of measurements. Eight to nine months of consecutive measurements seemed to give a good approximation of the 12 month average wind speed and monthly Weibull A parameters at both sites.

The implications of commencing a wind monitoring campaign or of using a dataset that commenced in a typically windy or calm period significantly impacted the results, particularly if attempting to project 12 month parameters using limited data during the earlier stages of the resource assessment campaign.

Uninterrupted wind measurement programmes enabled the projection of wind resources on a 12 month basis; the duration generally necessary to enable the utilisation of MCP techniques in conjunction with nearby stations possessing wind parameters time series of a long-term historical nature. In excess of eight consecutive months of measurements were required to project wind conditions at the site of interest to represent the 12 month behaviour.

Meanwhile, two MCP techniques were exercised on ever-increasing duration of concurrent data sets with each of the sites standing in as a longer-term reference station, the other being used as the candidate site. When used as reference, Site A appeared to give more reasonable estimates for Site B's 12 month average wind speed, and this after as little as 4 months of consecutive concurrent measurements. The percentage difference for the monthly Weibull A parameter also stabilized with the sites taking on the same roles as mentioned previously. The monthly k parameters were somewhat more difficult to predict and the significance of this parameter, which describes the way that the wind speeds were distributed, is not to be underestimated.

Finally, measured data sets from the two sites were also used to calibrate a commercial CFD wind modelling software program. Once again, the period when the field studies commenced had a marked impact on the results obtained, particularly during the earlier stages of the measurement campaign. After about four months of consecutive measurements, the CFD model was capable of generating consistent average wind speed estimates at the candidate site. With Site A providing the measured time series, CFD marginally over-estimated average wind speeds at Site B. With their roles switched, CFD results were somewhat lower than measured values for Site A. These results were consistent after 9 months of measured data had been compiled, irrespective of whether the measurement programme commenced during a windy or calm period of the year.

This work was envisaged to validate different wind resource assessment and scaling tools in a Mediterranean island context and will eventually be used to test the possibility of using MCP techniques in combination with CFD modelling to shorten candidate site field measurement timeframes.

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