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Off-shore Wind Atlas of the Central Aegean Sea: A simple comparison of NCEP/NCAR RE-analysis data, QuickSCAT and ENVISAT Synthetic Aperture Radar (SAR) by use of Wind Atlas Method

Ferhat Bingöl[1†], Charlotte Hassager[1], Ioanna Karagali[1], Jake Badger[1] , Merete Badger[1],Dimitri Foussekis[2], Morten Nielsen [1], Konstantinos Topouzelis[3],

[1]Denmark Technical University, Wind Energy, Frederiksborgvej 399 4000 Roskilde, Denmark,

[2]CRES - The Centre for Ren. Eng. Sources and Saving, Marathonos Ave, Pikermi Attiki, Greece

[3]University of the Aegean, Department of Marine Sciences, University Hill, 81100 Mitilene, Greece

[†] To whom correspondence should be addressed; E-mail: febi@dtu.dk.

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1 Introduction

Offshore wind energy is progressing rapidly in many parts of the world including Europe. While our understanding of offshore wind is growing parallel to that, most of the offshore wind development is located in shallow or transitional waters. Deep, open sea was never preferred by developers due to high costs, but with the new developments in floating turbine design, it seems that offshore wind parks in deep waters will also be a possibility in the future.

Whether on-shore or offshore, the first step of a site assessment is to estimate the wind resources. Usually well-known conventional methods are used to produce estimates of wind resources by means of at least one year data from a single or multiple points on the terrain. This criterion is difficult to satisfy in offshore locations where measurements are costly and sparse. Therefore other methods are required (e.g satellite imagery or re-analysis model results). Unfortunately all of these methods are still under development and do not provide data acceptable for bankable wind assessment reports. On the other hand, they give good indications of the geographical distribution of the wind resources and that is very useful for decision making and planning of feasibility studies and of actual project preparation.

Until now, several offshore wind resources (e.g. North Sea [1], Baltic Sea [2]) have been investigated by means of ENVISAT Synthetic Aperture Radar (SAR) data. In the current study we investigate the positive and the negative aspects of using SAR data at the Central Aegean Sea and compare with two other parallel developing techniques; NCEP/NCAR re-analysis based Ocean wind Atlas and scatterometer winds QuickSCAT [1]. WAsP software and/or method is used in all steps of the study.

2 Available Datasets

Three data sources are used in this study;

- **NCEP/NCAR:** Re-analysis data [3] for the 50-year period 1954 to 2003 are used. The data have approximately 2^o resolution, consist of 6-hourly output from the assimilation system. Therefore each wind atlas is a product of nearly 60000 samples. Wind Atlases at 4 locations in the Central Aegean sea were chosen for the selected area.
- **QuikSCAT:** With a daily global coverage of more than 90% of the world's oceans, QuickSCAT provides a valuable dataset with more than 10 years, from 1999 to 2009, of two daily observations at $10m$ a.s.l. Data are available at a 0.25^o grid. After the source data are filtered for rain, the grid points of the selected area include almost 5000 valid wind speed and wind direction measurements during the 10 years or the mission lifetime [4].
- **ENVISAT Synthetic Aperture Radar - SAR:** The mission is running since 2002, where high resolution wind fields can be retrieved at 10 m height a.s.l. DTU Wind Energy processes several SAR images a day. The Central Aegean dataset currently includes 500 ENVISAT ASAR WMS scenes from March 2010 to March 2012.SAR data has been used in several other places where in-situ measurement comparisons were available [1, 2].

3 Calculation domain

We have chosen to investigate a section of the Central Aegean Sea, based on the following criteria:

- **the least available spatial data**: To be able to make a full-comparison we had to limit the calculation zone according to the least available data set, which is QuickSCAT (Figure 1 - calculation boundary). This calculation domain is also used for the other two data sets.
- **the coast line**: Available data in coastal areas depends on the data source, therefore an island free zone in the Central Aegean is chosen and, furthermore, a $5km$ buffer zone is applied to any land in the selected domain.

[1]QuikScat data are produced by Remote Sensing Systems and sponsored by the NASA Ocean Vector Winds Science Team. Data are available at www.remss.com.

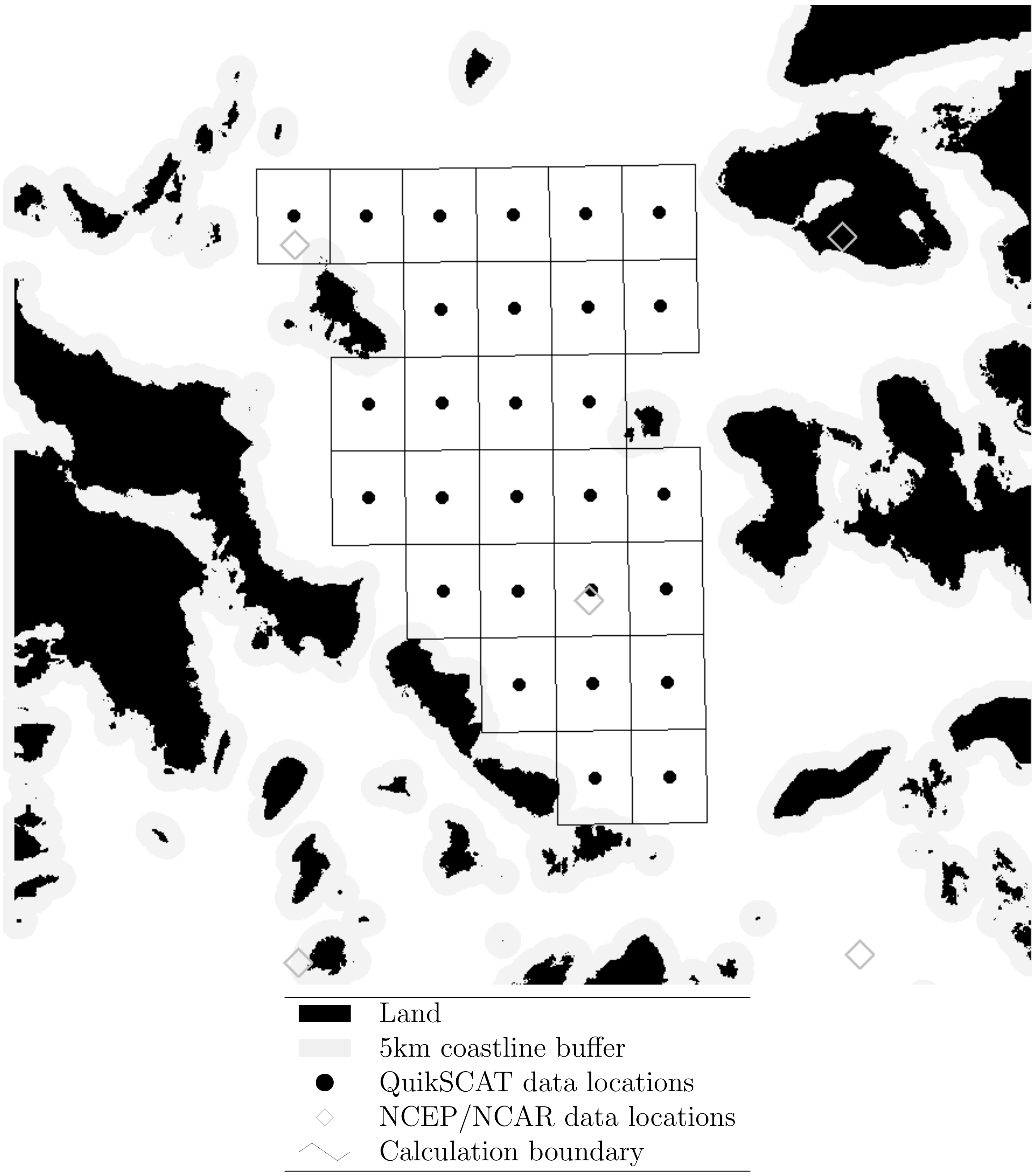

Figure 1: Available data points and calculation boundaries. The map has the borders of min(450000,4100000) and max(750000,4400000) (GRS87).

- **the seasonal coverage**: Data sets are neither from the same period nor have the same sampling frequency. This is the nature of data sets, but each data set is chopped for evenly distributed seasons and only full-year data sets are used. Therefore, seasonal variations are equally represented.

4 Method

Our final goal with our data sources was to create wind atlases to generate resource grids for certain areas. The subject in a 'wind atlas' is a systematic and comprehensive collection of regional wind climates (RWC) derived by the wind atlas methodology.

The wind atlas methodology in general was first developed and described in detail for the European Wind Atlas at DTU Wind Energy in 1989 [5]. The methodology is the core of the industry standard software WAsP [2].

The following steps are used to apply the Wind Atlas Method on each dataset.

1. A hi-definition elevation and roughness map of the the Central Aegean was created and used in all the steps below. The calculation domain is a sub-region of the calculation map which is at least 50 km away from each borders.

2. Each data set point is converted into a standard WAsP statistical "Observed Wind Climate" file. Such a file includes frequency and Weibull parameters of each wind sector. In our case we used 12 sectors.

3. Statistical files are converted into wind atlases. Each wind atlas includes an h x r size of matrix where h is the number of heights and r is the number of roughness values.

4. Each Wind Atlas is applied only to the area where its source data was collected. For example, a single NCEP/NCAR derived Wind Atlas (interpolation of four available data points) is used for the whole area while for QuickSCAT data, each grid point is only applied to the data area of has 0.25^o x 0.25^o. In the case of SAR the point calculation was made for each 1km to 1km areas.

5. If there are more than one areas available for any of the data set, the final results are combined in a single resource grid file (with the grid size 1km x 1km) for each dataset.

6. Due to the fact that the difference in data periods and the uncertainty of wind measurements are very high, it is not possible to compare spatial sensitivity with the calculated values. Therefore, each resource grid is normalized with its mean value.

[2]Further information about the methodology and the software can be found at www.wasp.dk, including a long list of references

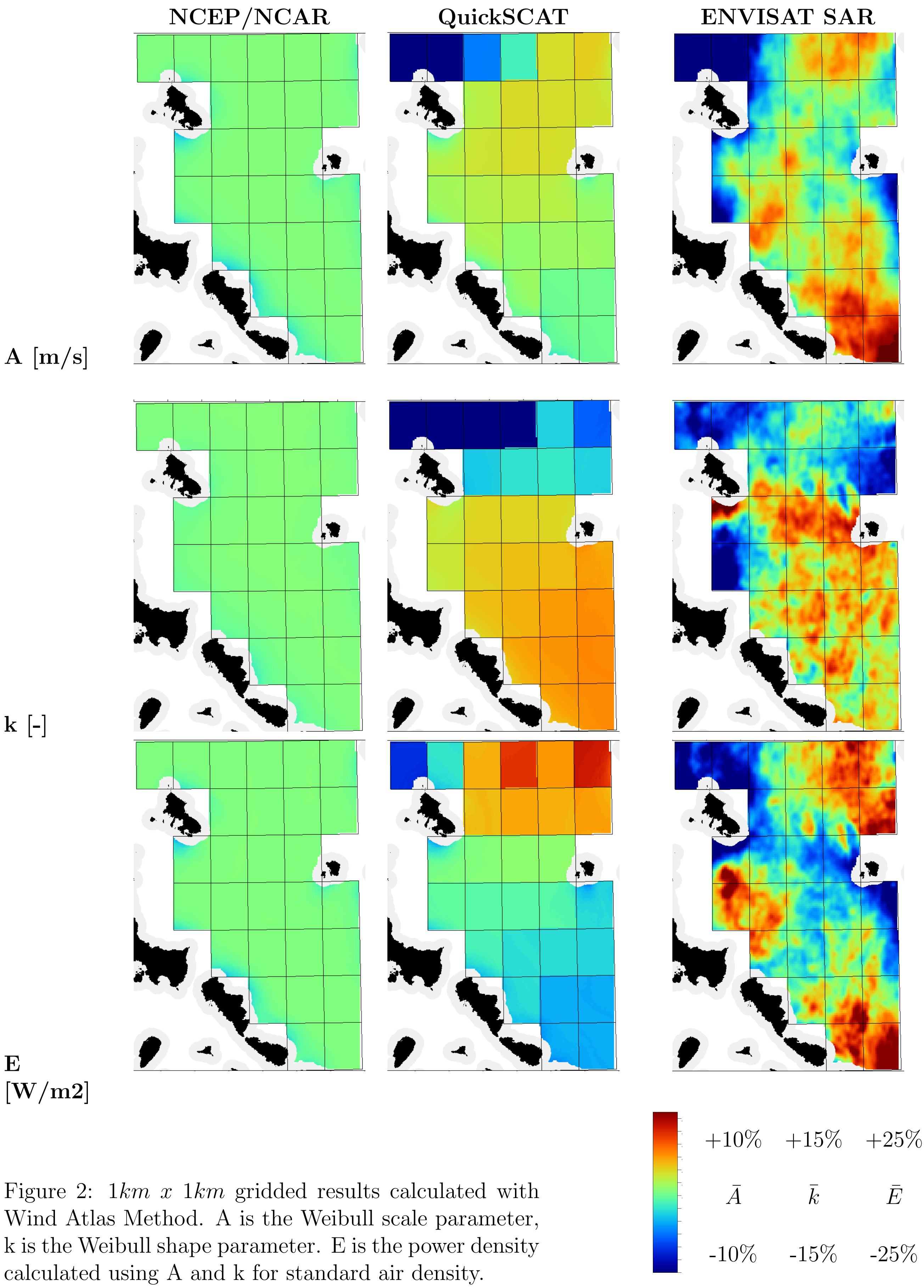

Figure 2: $1km$ x $1km$ gridded results calculated with Wind Atlas Method. A is the Weibull scale parameter, k is the Weibull shape parameter. E is the power density calculated using A and k for standard air density.

5 Results

NCEP/NCAR and QuickSCAT data have been analysed over the selected area by means of the WASP software while SAR data is analysed by means of a WAsP derived DTU Wind Energy in-house tool called s-WAsP [3]. Run results are combined in Figure 2.

The NCEP/NCAR derived ocean wind atlas captures only large-scale flow features. Flow features due to meso-scale phenomena are missing. This area provides a test bench for evaluating other wind atlas products derived from alternative reanalysis data set. This will an important element to the evaluation of the Global Wind Atlas project [4].

QuickSCAT has a higher than NCEP/NCAR and lower than ENVISAT SAR spatial detail. The averaging inherent in the NCEP/NCAR and in the wind retrieval process of QuikSCAT eliminates the small scale features seen by SAR.

6 Conclusion

One can rapidly calculate the wind resource map of an offshore location including statistical parameters by using the WAsP based tools we have created for different types of data sources.

A shortcoming of this study is the lack of validation with in-situ measurements which would greatly improve the usage of the datasets. It is intended that several on-shore and off-shore calculations are used in further studies.

Nevertheless, the results from this analysis can be used to identify possible locations for the installation of offshore masts for future campaigns, especially when the SAR results are used.

[3] s-WAsP is a special version of wind atlas methodology for the satellite wind speed measurements. The software is an in-house study and is not commercially available. For more information, contact; Charlotte Hassager [cbha@dtu.dk]

[4] The Global Wind Atlas [EUDP 11-II, Globalt Vind Atlas, 64011-0347] is a Danish contribution to the Clean Energy Ministerial Multilateral Working Group on Solar and Wind Technologies, Global Solar and Wind Atlas project.

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QuikScat data are produced by Remote Sensing Systems and sponsored by the NASA Ocean Vector Winds Science Team. Data are available at www.remss.com.

ENVISAT SAR data are provided by the European Space Agency.

References

[1] M. Badger, J. Badger, M. Nielsen, C.B. Hasager, and A. Pena. Wind class sampling of satellite SAR imagery for offshore wind resource mapping. *Appl. Meteorol. Climatol.*, 49:2474–2491, 2010.

[2] Charlotte Bay Hasager, Merete Badger, Alfredo Pena Diaz, Xiaoli Guo Larsen, and Ferhat Bingol. SAR-based wind resource statistics in the baltic sea. *Remote Sensing*, 3(1):117–144, 2011.

[3] Kalnay et al. The ncep/ncar 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, 77:437–470, 1996.

[4] Ioanna Karagali. *Offshore Wind Energy: Wind and Sea Surface Temperature from Satellite Observations*. PhD thesis, DTU Wind Energy, 2012.

[5] I. Troen and E.L. Petersen. European wind atlas. Technical report, Risø National Laboratory, Roskilde, 1989.