

ESA ResGrow: Trial cases for SAR lifting

Aegean Sea



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DTU Wind Energy Report-I-0375

February 2015

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Titel: ESA ResGrow: Trial cases for SAR lifting. Aegean Sea

February 2015

Kontrakt nr.:

[Tekst]

Projektnr.:

[Tekst]

Sponsorship:

[Tekst]

Forside:

[Tekst]

Sider: [Tekst]

Tabeller: [Tekst]

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Preface

Expansion of the Market for EO Based Information Services in Renewable Energy (ResGrow) is a project funded by the European Space Agency (ESA). During phase II of the project (2014-15), the Department of Wind Energy at the Technical University of Denmark (DTU Wind Energy) works together with partners from the wind energy industry in order to develop innovative products based on Earth Observation data and to assess the practical usability of these products.

This report presents results related to lifting of wind maps retrieved from satellite Synthetic Aperture Radar (SAR) over the Aegean Sea. For this case study DTU Wind Energy collaborates with the Hellenic Wind Energy Association. Preliminary results have been presented to HWEA and their feedback has been incorporated in this final version of the report. In summary, the following updates have been made:

- Overview maps of the 10-m mean wind speed are added with coverage and color scaling similar to HWEA's own results (not shown).
- Wind resource statistics for the 10-m level, including wind roses, are added for every site.
- Editorial changes are made according to HWEA's suggestions.

Roskilde, February 2015

Merete Badger
Senior Scientist

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1. Approach

The purpose of this analysis is to bring 10-m mean winds retrieved from satellite Synthetic Aperture Radar (SAR) up to higher levels in the atmosphere where wind turbines operate. This requires information about the atmospheric stability from a different source – in this case from the Weather Research and Forecasting (WRF) model. Previous work has shown that a correction of the vertical wind profile for atmospheric stability effects can be done on the basis of WRF data. However, the method is only robust if the long-term average rather than the instant effect of atmospheric stability is considered (Peña & Hahmann, 2012). Our approach is therefore to combine the 10-m mean wind speed from satellite SAR data with a long-term average stability correction based on WRF simulations in order to calculate profiles of the mean wind speed up to 100 m.

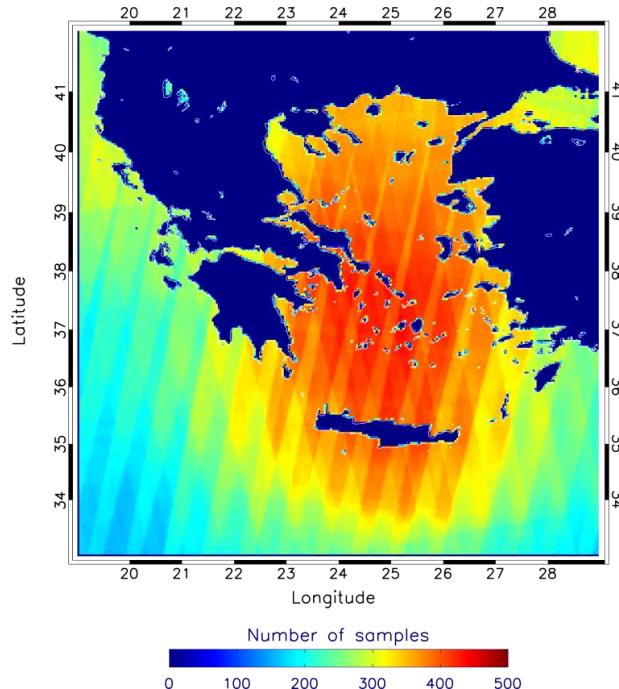
Our calculation of the long-term atmospheric stability correction follows the method described by Kelly & Gryning (2010). Once the stability correction parameter, Ψ is known, the wind profile is calculated as follows:

$$\left\langle \frac{\kappa u(z)}{u_*} \right\rangle = \ln \left(\frac{z}{z_0} \right) - \langle \psi_m \rangle$$

where u is wind speed, u_* is friction velocity, κ is von Karman's constant, z is the height, and z_0 the aerodynamic roughness length. The brackets denote long-term mean values.

2. Satellite data

A comprehensive archive of more than 2.000 SAR scenes from the Envisat mission by the European Space Agency have been collected and processed to ocean wind fields following the same approach as in the project NORSEWind (Hasager et al., 2015). The satellite data have been acquired during the period 2002-12. The figure below shows the coverage of the wind maps over the Aegean Sea.

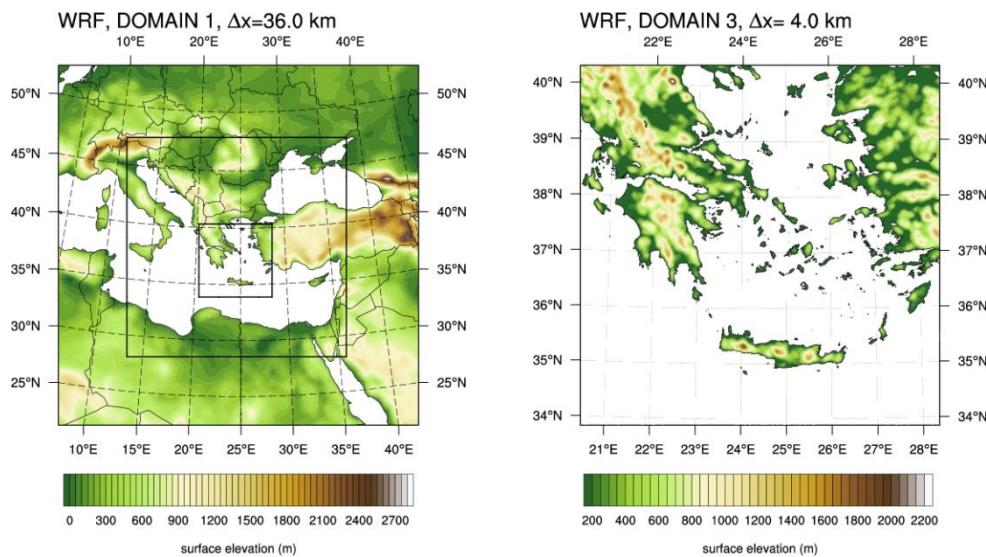


Map showing the number of overlapping satellite SAR scenes for the Aegean Sea.

The output parameter of the SAR wind retrieval is the Equivalent Neutral Wind speed (ENW) which represents the wind speed at neutral atmospheric conditions. It is retrieved with a spatial resolution of 0.5 km for the **instant** wind speed maps.

3. WRF model data

WRF simulations have been carried out over the Aegean Sea within three nested domains with different spatial resolutions. A detailed description of the model setup is given in Hahmann et al. (2014). Here we use the inner modeling domain which covers the Aegean Sea at a 4-km spatial resolution with hourly outputs. The model parameters used in this analysis are the air temperature (T2), heat fluxes (HFX), and friction velocity (UST) for the period 2002-12.



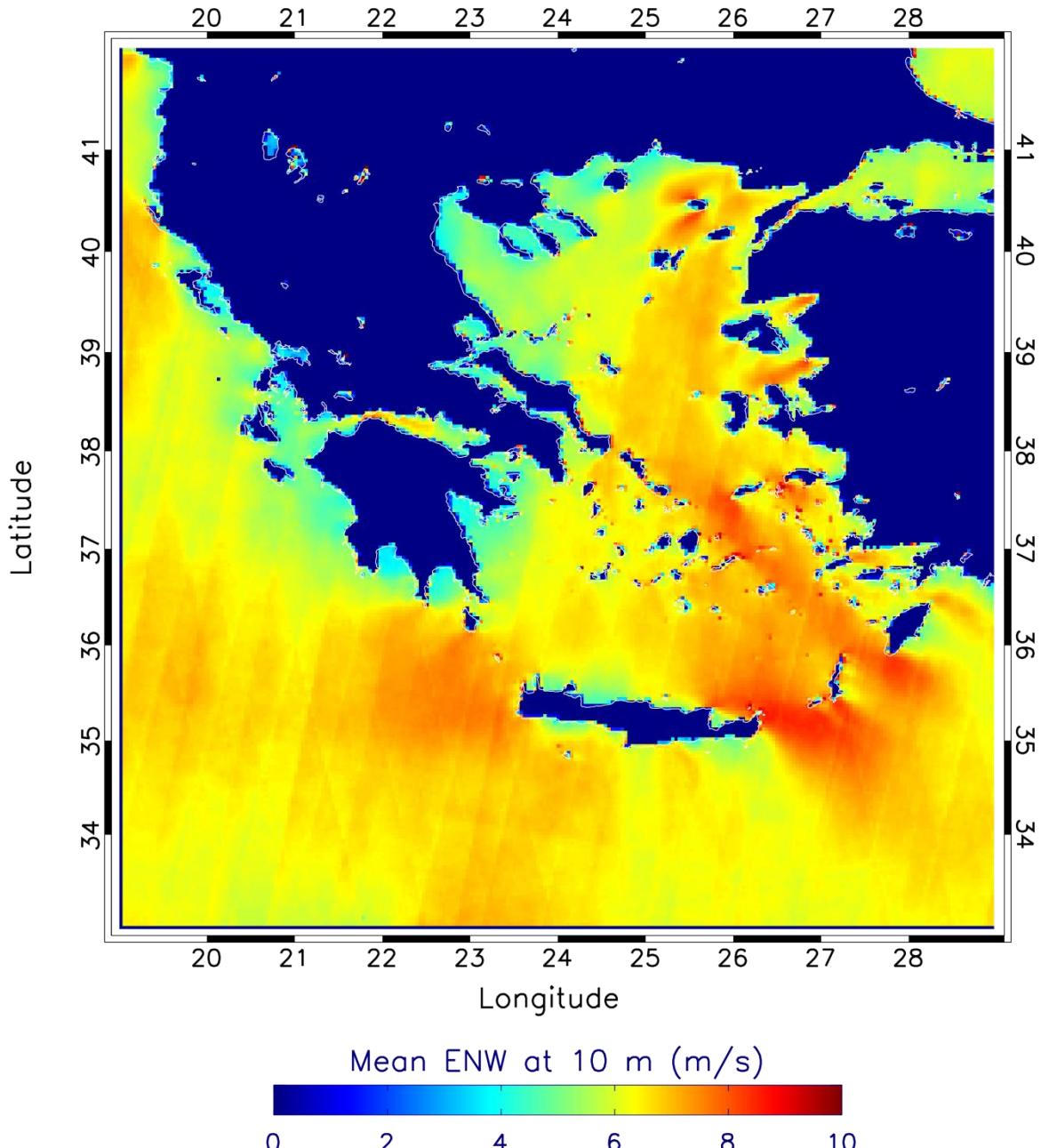
Maps showing (left) an overview of the three nested WRF domains and (right) the inner domain simulated at 4 km x 4 km spatial resolution which is used for the extrapolation of SAR winds.

4. Presentation of results

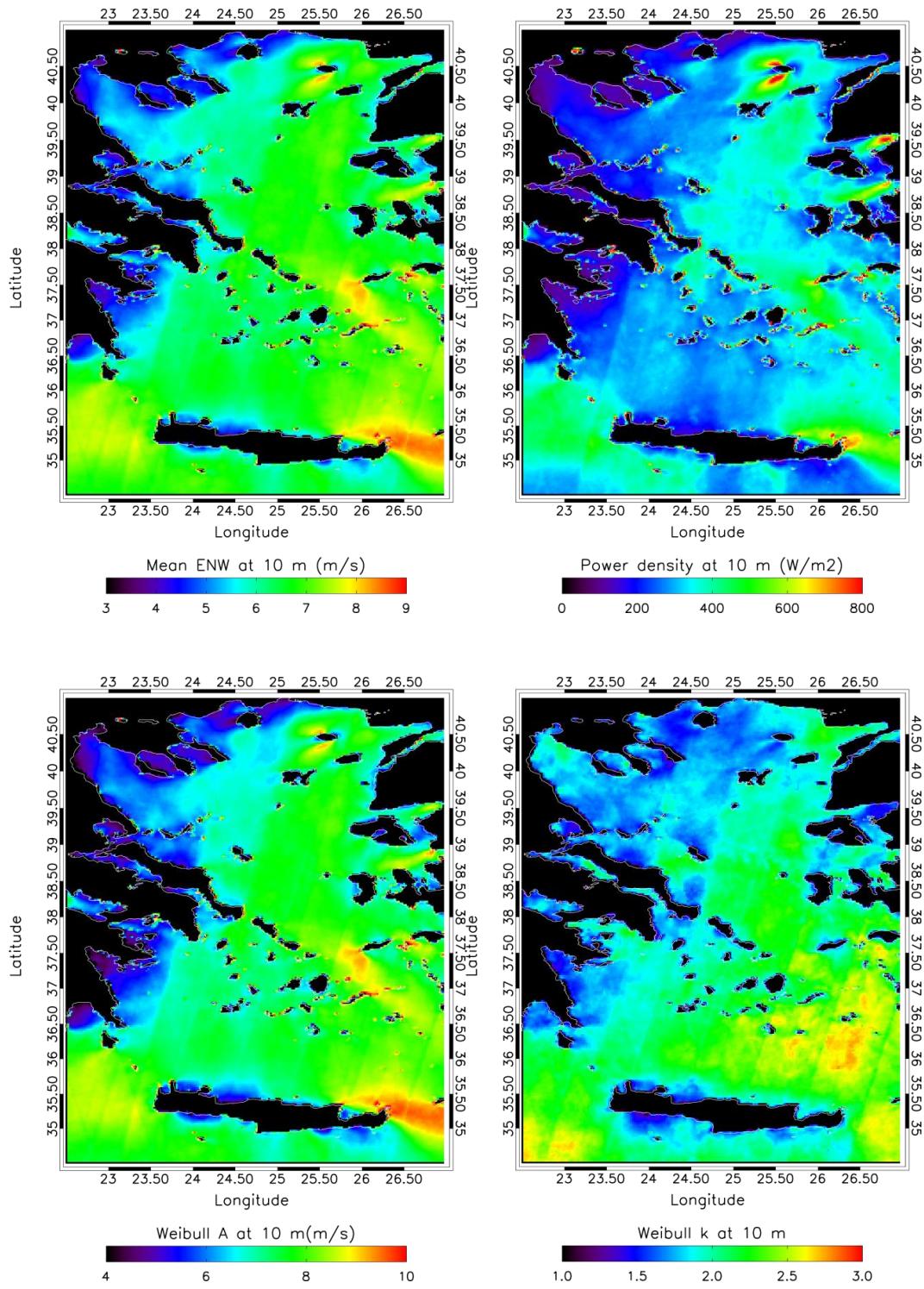
Results are presented in the following sections. We first report the 10-m wind resource maps from the satellite SAR data found through Weibull statistics (see Hasager et al., 2015 for details). The spatial resolution of the SAR based wind **resource** maps is 0.02° latitude and longitude. Next results of vertical extrapolation of the SAR mean wind speed is presented for the area. Maps of the 100-m mean wind speed are shown with and without a correction for atmospheric stability effects from WRF. Finally, 10-m wind resource statistics and vertical profiles of the long-term stability correction parameter and the mean wind speed are shown for specific points. HWEA has supplied a list of polygons, which indicate the location of future bottom mounted wind farms (Phase I) and floating wind farms (Phase II) in the Aegean Sea. In connection with this analysis we present results for a point near the centre of each wind farm (see further details below).

5. 10-m wind resource maps from satellite SAR

We first present an overview map of the mean wind speed at 10 m from SAR. We then focus on a smaller area, the Aegean Sea, where the number of overlapping satellite SAR scenes is 300 or higher.

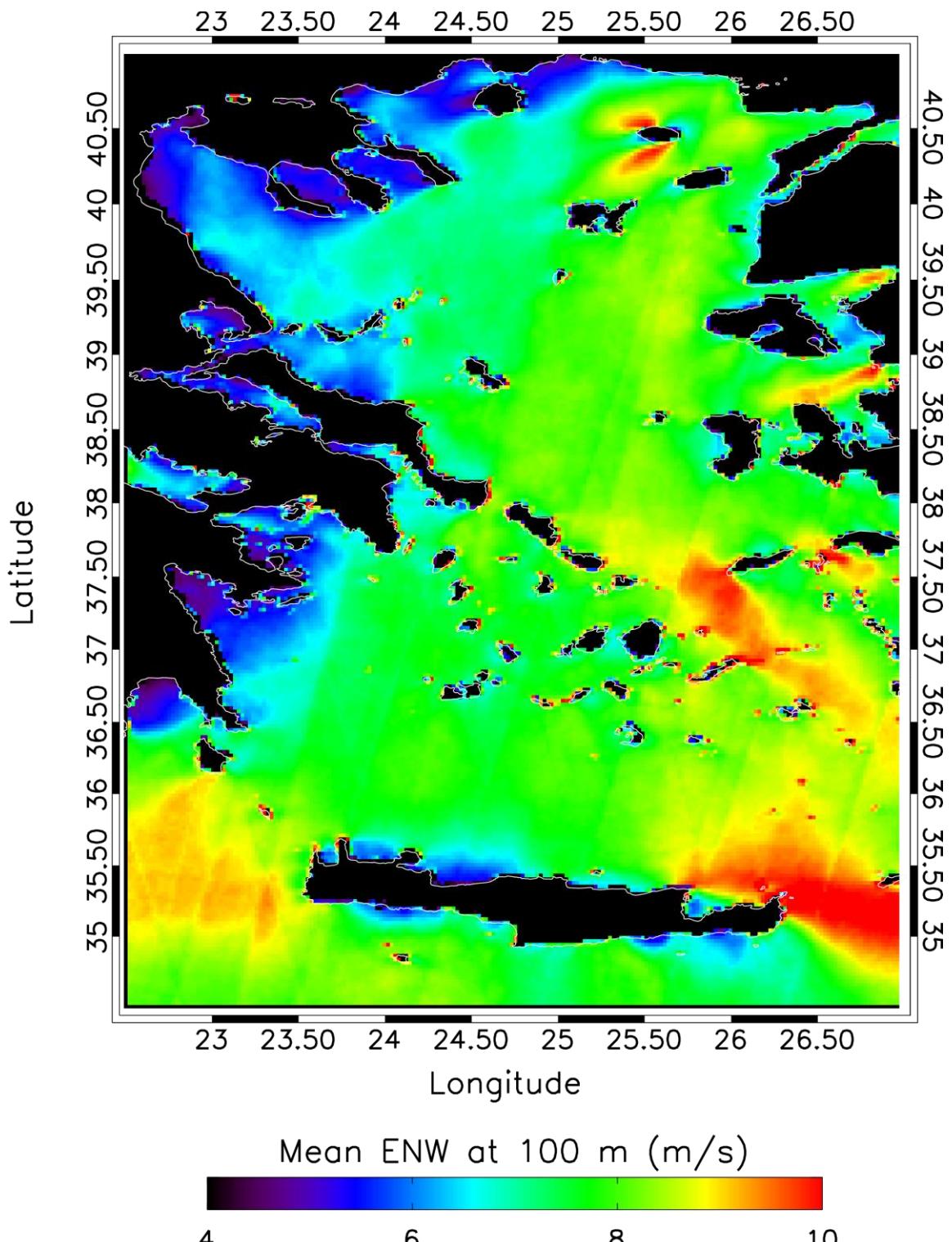


Map showing the mean wind speed (ENW) from SAR for the longitude range 19-29°E and the latitude range 33-42°N. The map coverage and color scaling is approximately the same as for results provided by HWEA (not shown here).

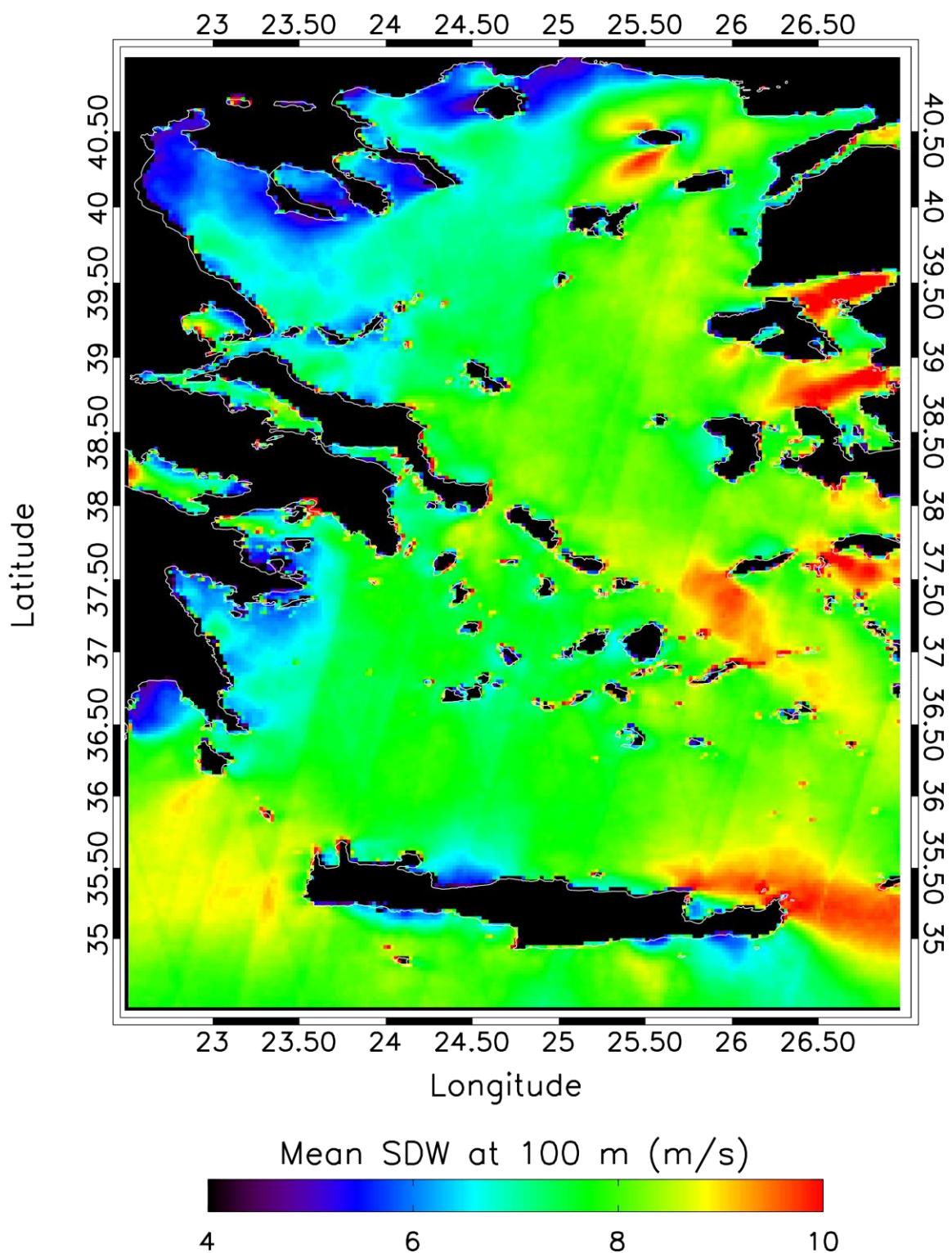


Maps showing wind resources from SAR at the 10-m level. Upper left: mean wind speed (ENW), upper right: power density, lower left: Weibull scale parameter (A), lower right: Weibull shape parameter (k). Black areas represent the land and islands.

6. 100-m mean wind speed maps from satellite SAR



Map showing the mean SAR wind speed extrapolated to the 100-m level **without any consideration of atmospheric stability effects**. This gives the Equivalent Neutral Wind speed (ENW).



7. Phase I: Bottom mounted wind farms

Of the 15 phase I wind farm locations HWEA has provided, nine were located within an area where the coverage of SAR and WRF made it possible to generate extrapolated SAR winds. These locations are shown on the map below. The locations Kimi and Petalioi I/II did not give meaningful stability correction profiles and were therefore omitted from the analysis. This was most likely due to their close proximity to the land such that the WRF simulations did not represent true offshore conditions.



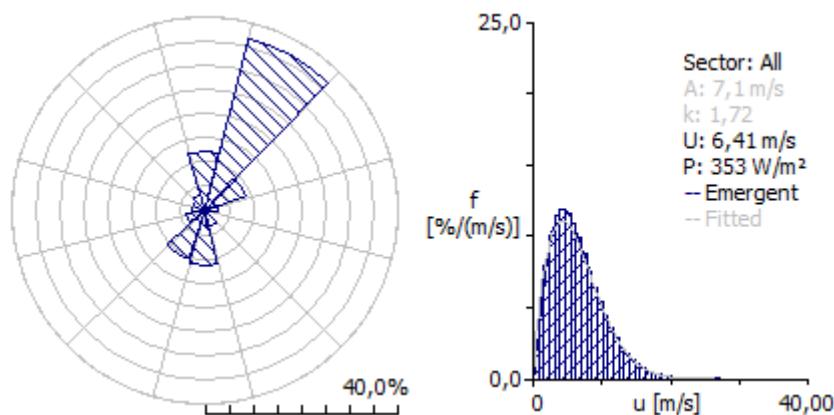
Map showing the Phase I wind farm locations in the Aegean Sea where SAR wind extrapolation to 100 m has been performed. Image courtesy Google Earth.

In the following, results are presented for a point near the centre of each wind farm. We first present wind resources at the 10-m level calculated through Weibull fitting. We then show vertical profiles of the long-term atmospheric stability correction and the mean wind speed. The mean wind speeds are shown with and without the atmospheric stability correction to illustrate the effect of including stability information from WRF for each site. Note that the results are not yet validated.

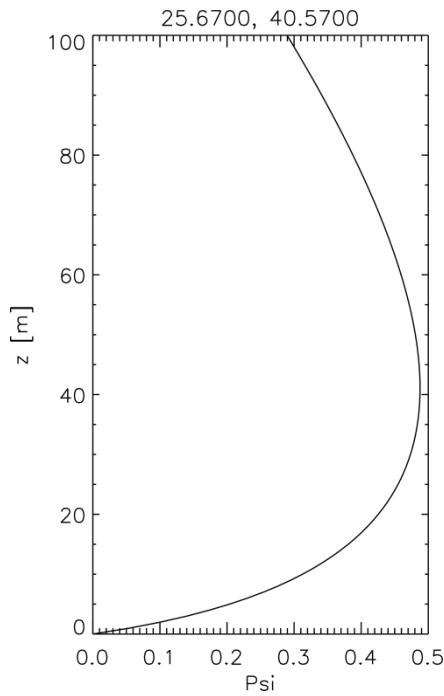
7.1 Samothraki

Site description: 'SAR 40.57N 25.67E GridResolution=0.02'; Position: 40,57°N 25,67°E; Height: 10,00 m a.g.l.

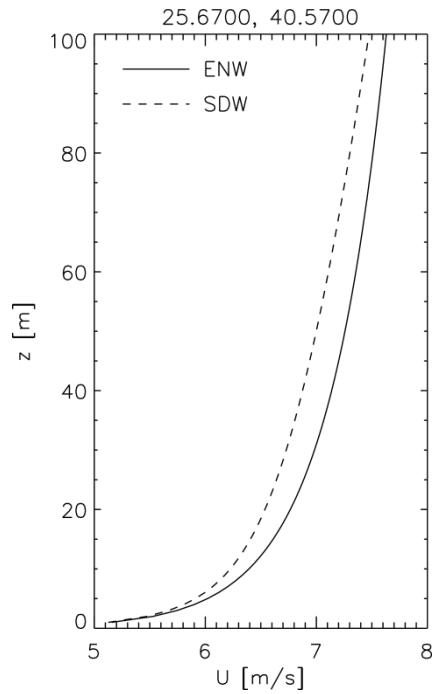
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,41	unknown
Mean power density [W/m ²]	unknown	353 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	6,9	9,0	6,6	8,3	12,5	7,5	6,6	4,2	5,4	4,2	5,6	5,9
k	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,05	2,06	2,06
U	6,07	7,98	5,85	7,36	11,0	6,60	5,83	3,72	4,76	3,76	4,96	5,21
P	254	578	228	453	153	327	225	58	123	61	139	161
f	12,4	36,8	8,7	2,7	1,2	3,4	11,2	10,7	4,0	2,7	2,7	3,7



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

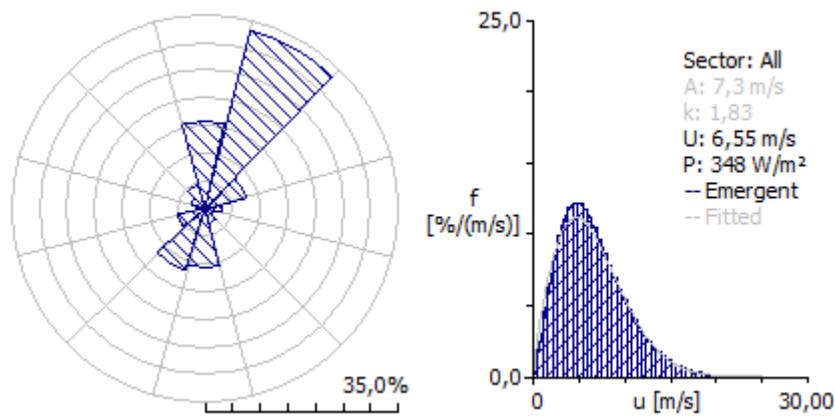


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

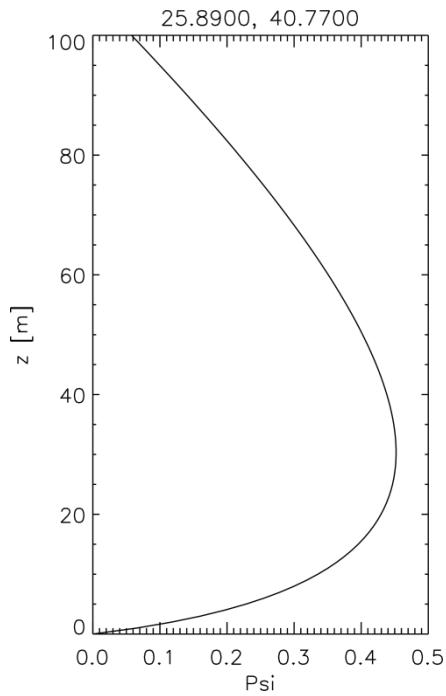
7.2 Alexandroupoli

Site description: 'SAR 40.77N 25.89E GridResolution=0.02'; Position: 40,77°N 25,89°E; Height: 10,00 m a.g.l.

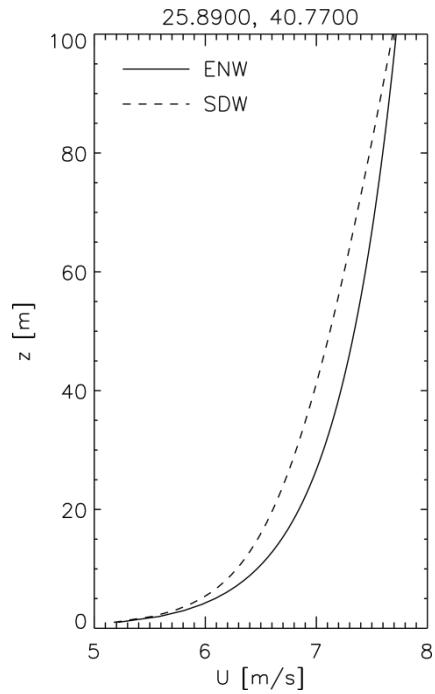
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,55	unknown
Mean power density [W/m ²]	unknown	348 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	8,1	9,4	6,9	4,7	6,8	9,0	5,9	5,4	4,1	6,1	5,6	6,2
k	2,23	2,23	2,23	2,23	2,23	2,23	2,23	2,23	2,23	2,23	2,23	2,23
U	7,17	8,34	6,10	4,13	6,00	8,01	5,23	4,79	3,66	5,39	4,93	5,46
P	390	613	240	75	229	544	151	116	52	165	127	172
f	15,8	33,1	7,6	2,9	1,6	2,5	10,7	11,6	5,3	1,6	2,9	4,4



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

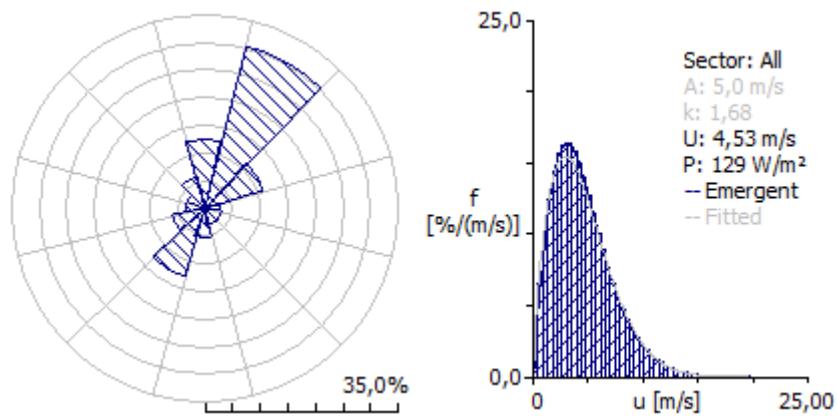


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

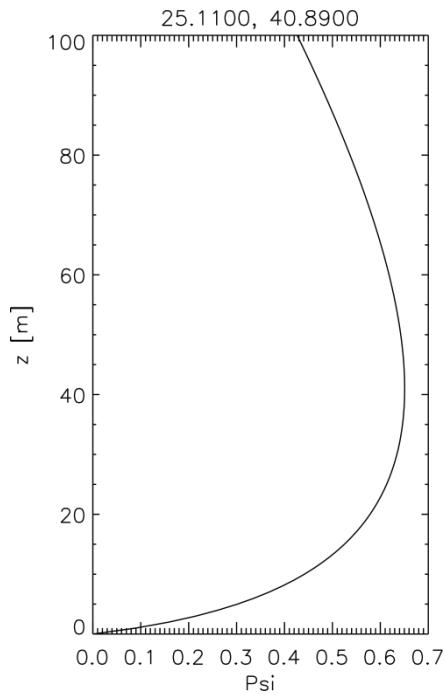
7.3 Fanari

Site description: 'SAR 40.89N 25.11E GridResolution=0.02'; Position: 40,89°N 25,11°E; Height: 10,00 m a.g.l.

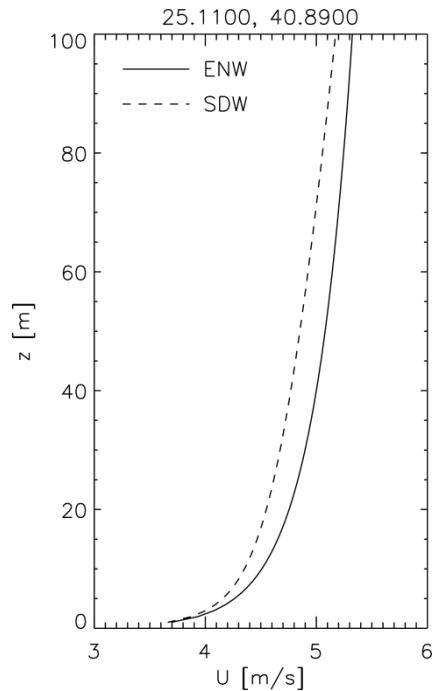
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	4,53	unknown
Mean power density [W/m ²]	unknown	129 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	5,6	6,4	5,1	5,0	4,8	5,7	4,0	3,8	3,8	3,5	4,0	4,2
k	1,90	1,90	1,90	1,90	1,90	1,90	1,90	1,90	1,90	1,89	1,90	1,90
U	4,98	5,66	4,52	4,43	4,25	5,02	3,57	3,42	3,35	3,06	3,58	3,71
P	153	224	114	107	95	156	56	49	46	36	57	63
f	12,5	30,3	11,1	2,8	3,0	3,2	5,2	12,9	6,1	3,4	3,4	6,2



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

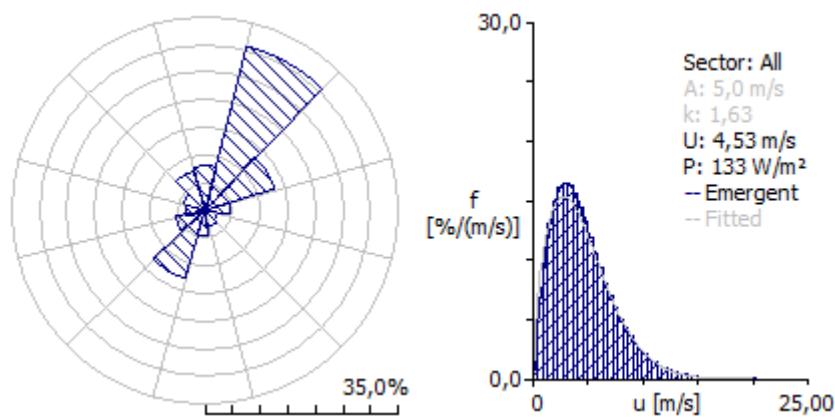


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

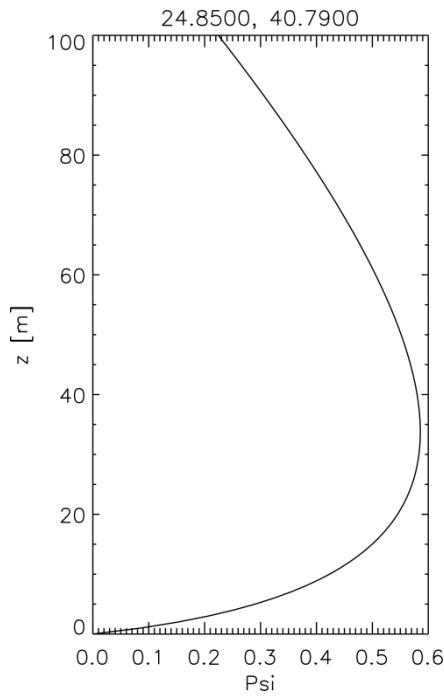
7.4 Thasos

Site description: 'SAR 40.79N 24.85E GridResolution=0.02'; Position: 40,79°N 24,85°E; Height: 10,00 m a.g.l.

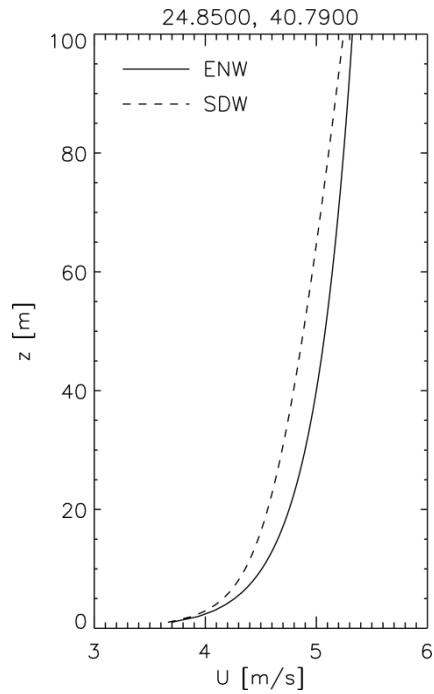
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	4,53	unknown
Mean power density [W/m ²]	unknown	133 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	5,5	6,6	5,1	5,0	5,5	5,2	4,4	3,7	3,3	2,9	3,9	4,1
k	1,91	1,91	1,91	1,91	1,91	1,91	1,91	1,92	1,92	1,91	1,92	1,91
U	4,88	5,90	4,52	4,48	4,89	4,57	3,93	3,30	2,94	2,61	3,46	3,60
P	142	251	113	110	143	117	74	44	31	22	51	57
f	8,3	30,6	13,1	4,5	2,4	2,9	4,4	12,8	5,7	3,6	4,1	7,4



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

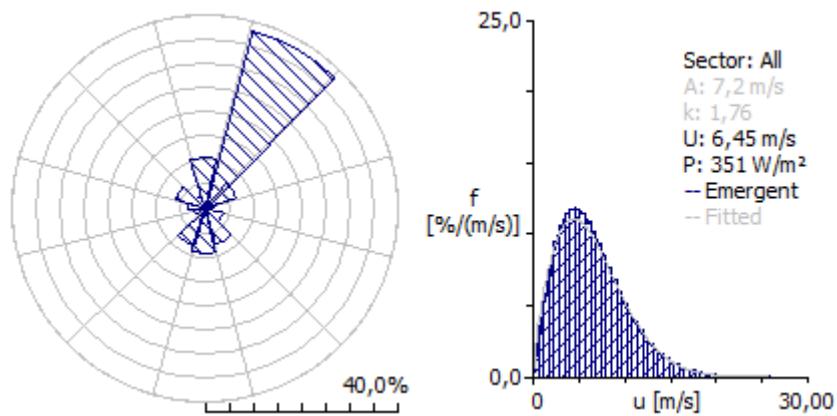


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

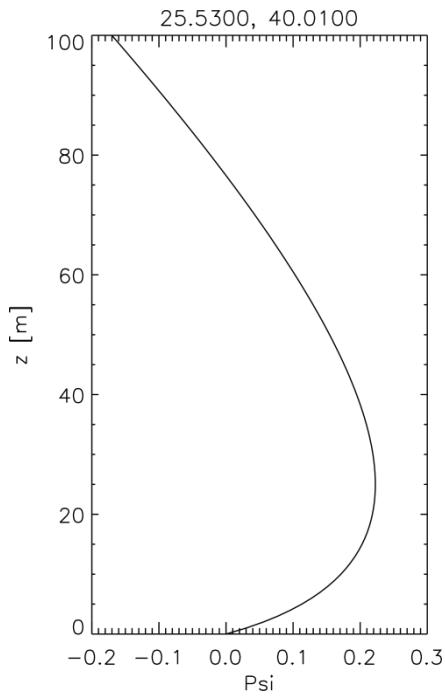
7.5 Limnos I

Site description: 'SAR 40.01N 25.53E GridResolution=0.02'; Position: 40,01°N 25,53°E; Height: 10,00 m a.g.l.

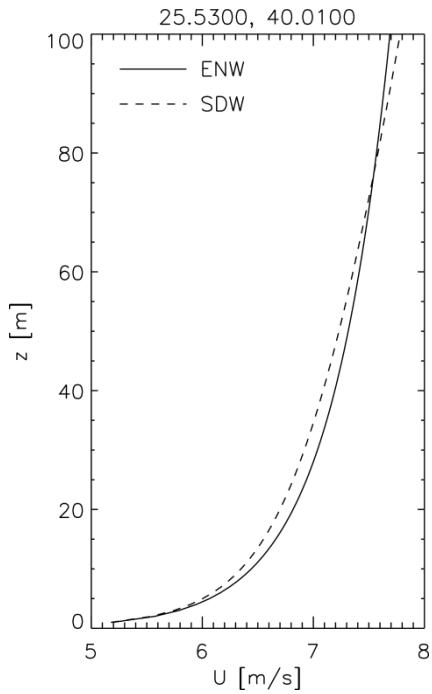
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,45	unknown
Mean power density [W/m ²]	unknown	351 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	6,5	9,0	7,4	5,3	7,1	7,5	5,9	4,9	5,8	4,0	5,6	7,3
k	2,04	2,04	2,04	2,04	2,04	2,04	2,04	2,04	2,04	2,04	2,04	2,04
U	5,79	7,97	6,59	4,73	6,33	6,69	5,20	4,38	5,17	3,55	4,93	6,48
P	223	583	330	122	291	344	161	97	159	52	138	313
f	10,4	38,0	6,7	1,7	3,8	7,4	9,2	7,9	2,1	3,6	6,3	2,8



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

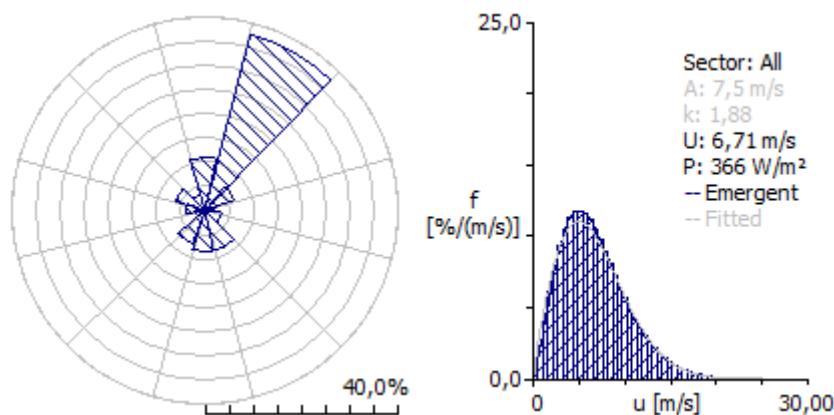


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

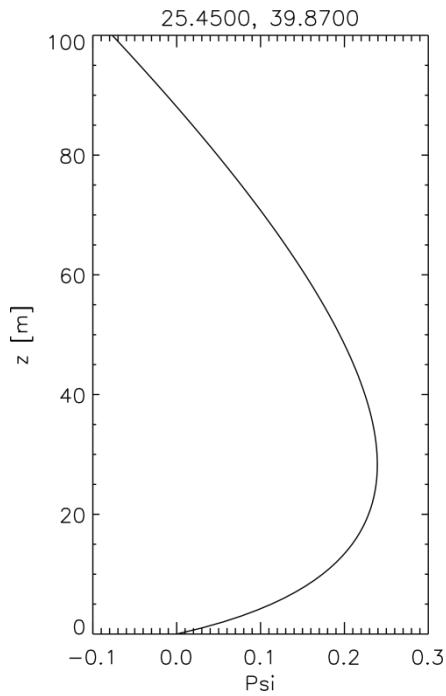
7.6 Limnos II

Site description: 'SAR 39.87N 25.45E GridResolution=0.02'; Position: 39,87°N 25,45°E; Height: 10,00 m a.g.l.

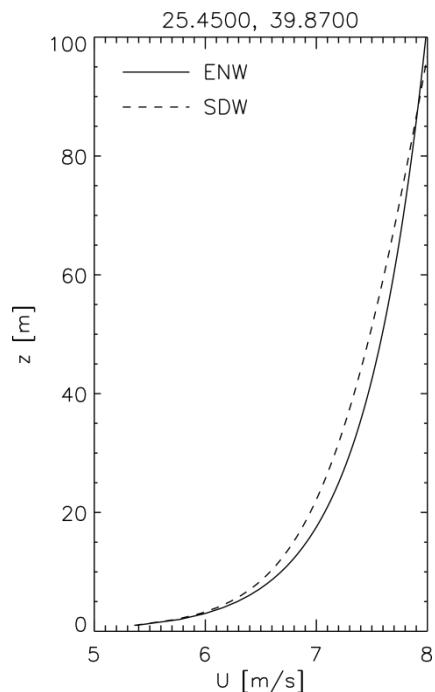
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,71	unknown
Mean power density [W/m ²]	unknown	366 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	7,3	9,4	7,6	5,4	6,6	7,9	5,8	5,4	5,9	4,0	6,2	6,5
k	2,21	2,22	2,21	2,21	2,21	2,21	2,21	2,21	2,21	2,22	2,21	2,21
U	6,49	8,33	6,69	4,82	5,81	7,03	5,10	4,80	5,26	3,52	5,49	5,75
P	292	613	319	119	209	371	141	117	155	46	176	203
f	10,8	37,3	6,4	2,0	3,4	8,6	8,5	7,3	1,9	3,8	6,4	3,6



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

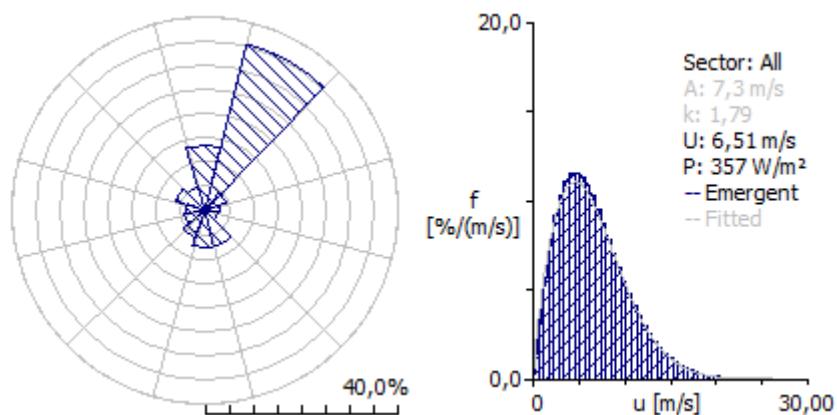


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

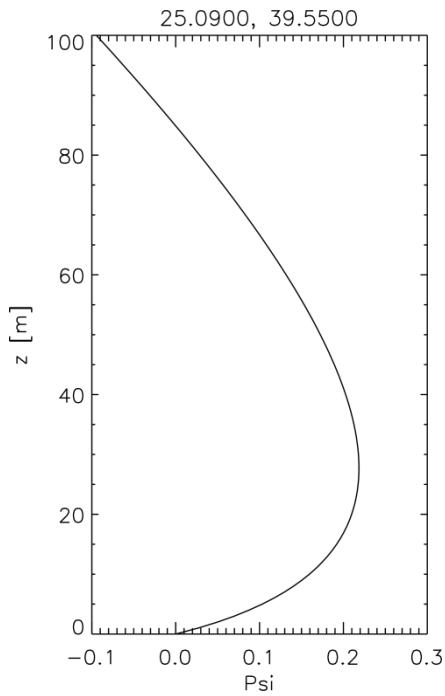
7.7 Ai Stratis I

Site description: 'SAR 39.55N 25.09E GridResolution=0.02'; Position: 39,55°N 25,09°E; Height: 10,00 m a.g.l.

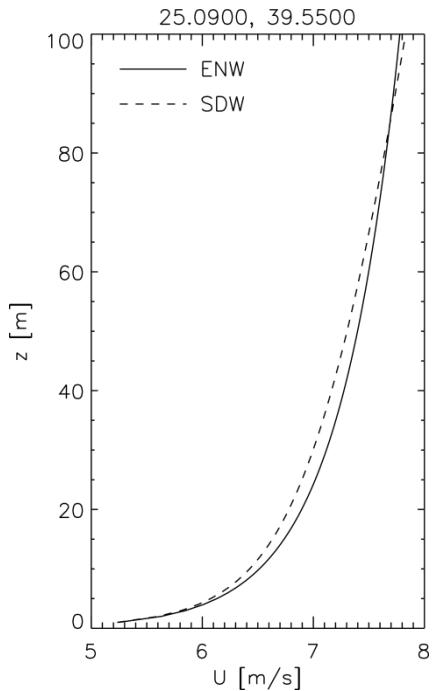
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,51	unknown
Mean power density [W/m ²]	unknown	357 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	8,0	8,7	6,4	7,5	5,4	7,6	7,3	5,1	5,5	4,4	6,3	5,1
k	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00
U	7,11	7,75	5,71	6,62	4,78	6,73	6,48	4,49	4,84	3,94	5,61	4,53
P	420	544	219	341	128	357	318	106	133	72	207	109
f	13,4	35,3	4,9	3,0	2,7	7,6	7,5	6,0	4,3	3,9	6,4	5,1



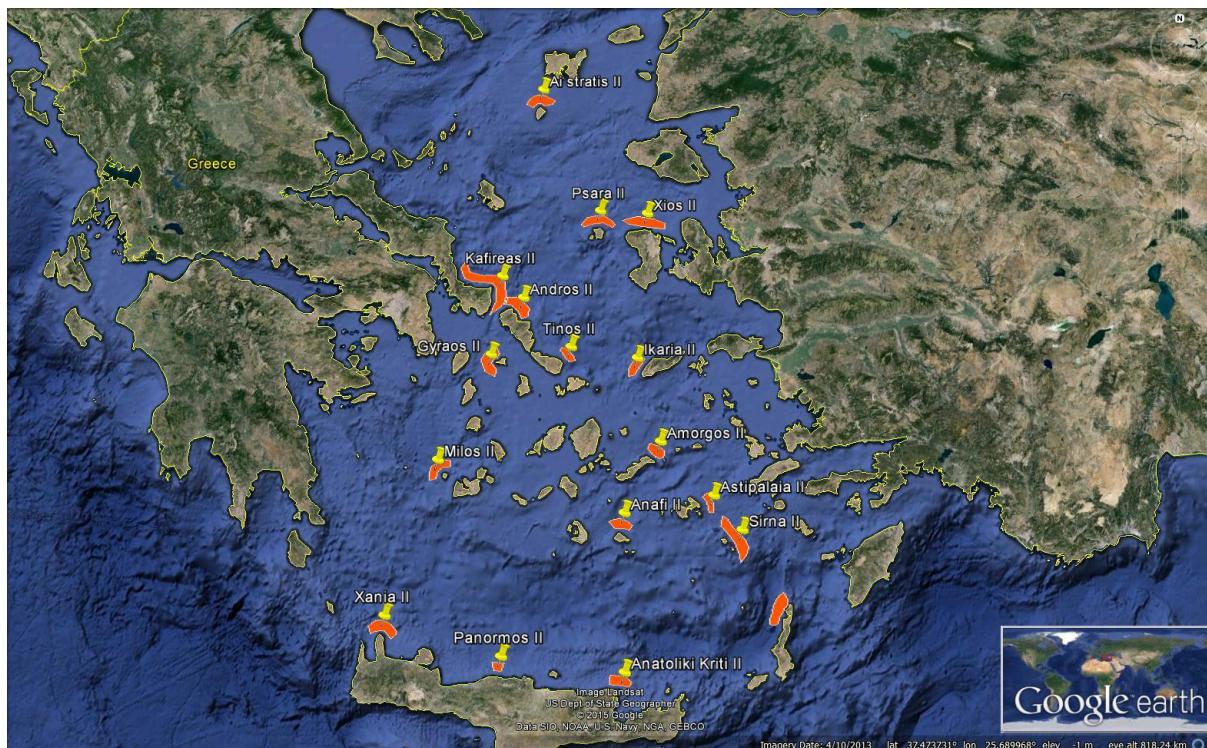
Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.



Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

8. Phase II: Floating wind farms

Of the 17 Phase II wind farm locations HWEA has provided, 16 were located within an area where the coverage of SAR and WRF made it possible to generate extrapolated SAR winds. These locations are shown on the map below. The locations Xania II and Panormos II did not give meaningful stability correction profiles and were therefore omitted from the analysis. This was most likely due to their close proximity to the island of Crete such that the WRF simulations did not represent true offshore conditions.



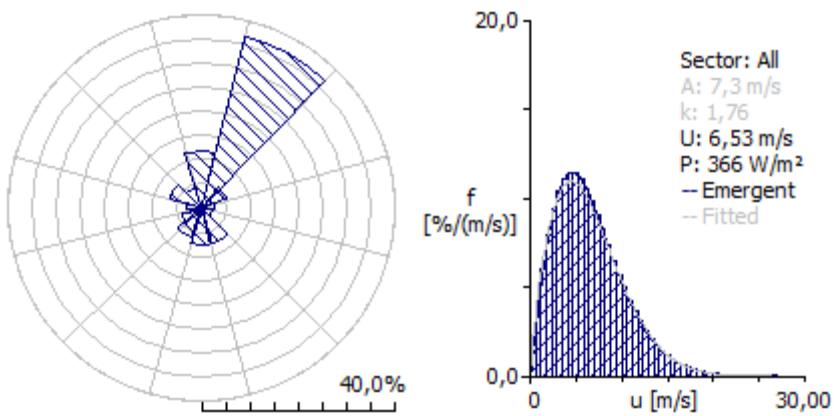
Map showing the Phase II wind farm locations in the Aegean Sea where SAR wind extrapolation to 100 m has been performed. Image courtesy Google Earth.

In the following, results are presented for a point near the centre of each wind farm. We first present wind resources at the 10-m level calculated through Weibull fitting. We then show vertical profiles of the long-term atmospheric stability correction and the mean wind speed. The mean wind speeds are shown with and without the atmospheric stability correction to illustrate the effect of including stability information from WRF for each site. Note that the results are not yet validated.

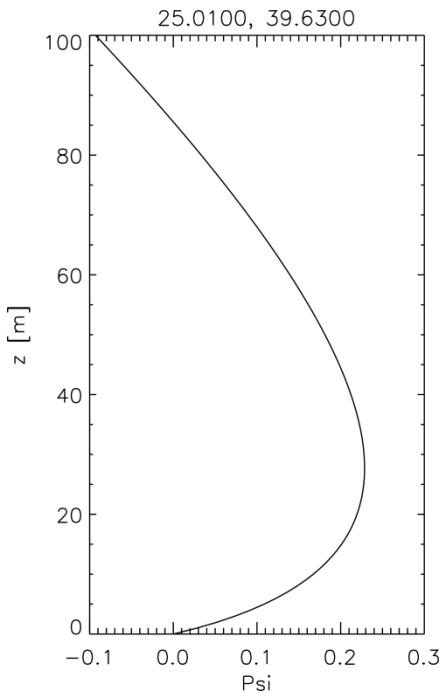
8.1 Ai Stratis II

Site description: 'SAR 39.63N 25.01E GridResolution=0.02'; Position: 39,63°N 25,01°E; Height: 10,00 m a.g.l.

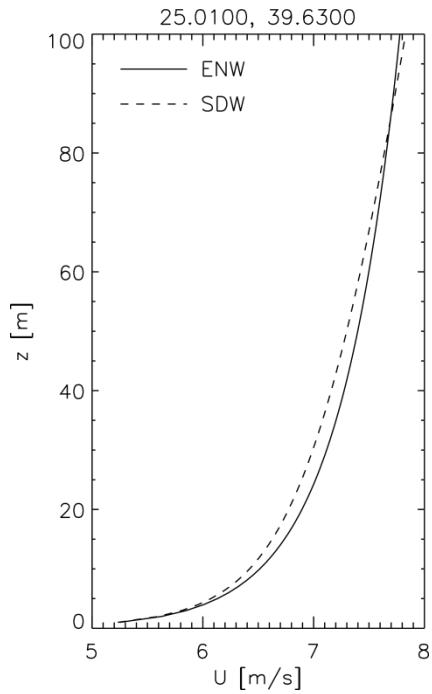
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,53	unknown
Mean power density [W/m ²]	unknown	366 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	7,3	8,8	7,2	5,5	6,5	7,5	7,4	5,9	5,4	4,3	5,9	5,6
k	1,94	1,95	1,95	1,95	1,95	1,95	1,95	1,95	1,95	1,95	1,95	1,95
U	6,45	7,81	6,40	4,92	5,77	6,67	6,58	5,22	4,75	3,80	5,22	4,97
P	323	572	314	143	231	356	342	171	129	66	171	147
f	11,8	36,8	5,7	2,7	2,3	7,8	7,4	6,5	4,6	3,1	6,9	4,4



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

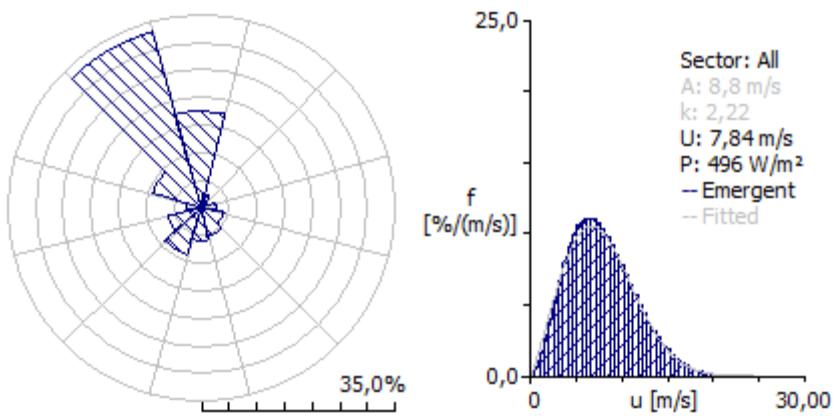


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

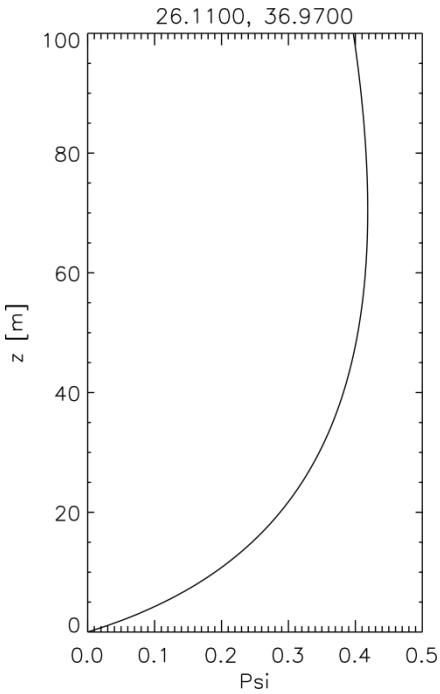
8.2 Amorgos II

Site description: 'SAR 36.97N 26.11E GridResolution=0.02'; Position: 36,97°N 26,11°E; Height: 10,00 m a.g.l.

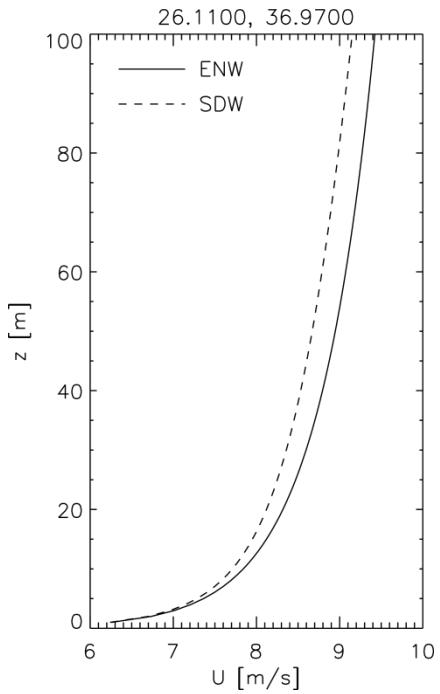
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	7,84	unknown
Mean power density [W/m ²]	unknown	496 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	9,9	6,0	6,5	5,0	9,5	10,6	8,9	6,2	7,0	5,3	7,5	10,2
k	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66
U	8,84	5,38	5,79	4,49	8,47	9,38	7,90	5,51	6,19	4,70	6,63	9,10
P	639	144	180	84	561	764	456	155	220	96	270	697
f	17,6	2,8	1,3	2,9	4,1	5,1	6,1	8,8	6,2	2,8	9,3	33,0



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

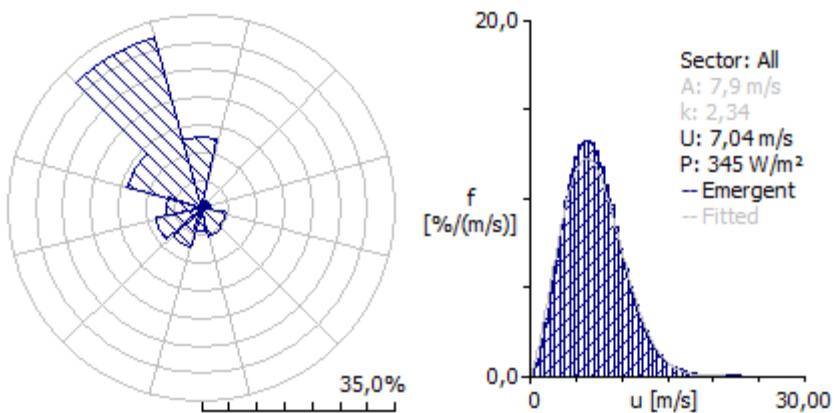


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

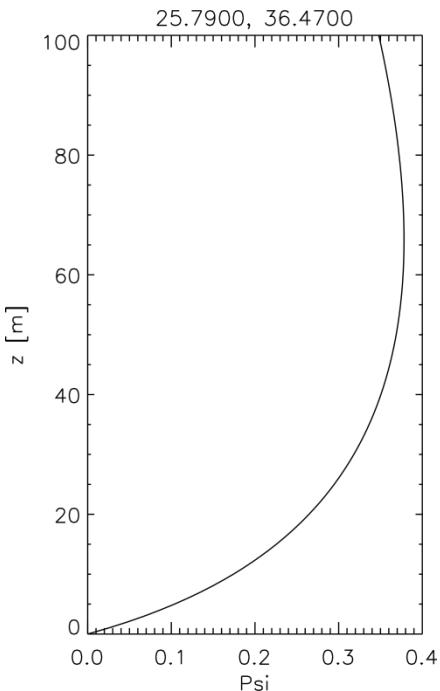
8.3 Anafi II

Site description: 'SAR 36.47N 25.79E GridResolution=0.02'; Position: 36,47°N 25,79°E; Height: 10,00 m a.g.l.

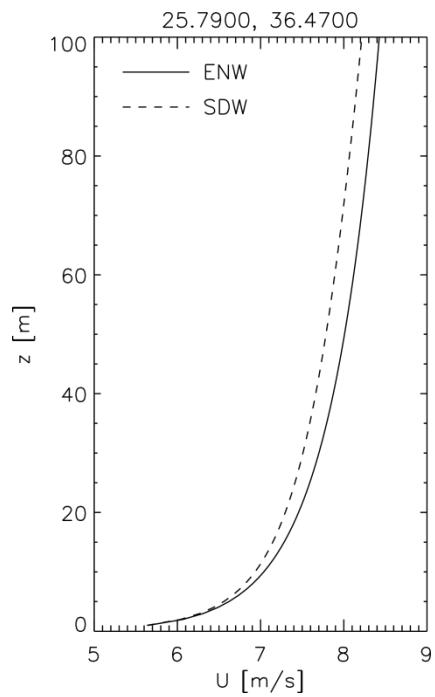
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	7,04	unknown
Mean power density [W/m ²]	unknown	345 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	8,2	6,1	5,8	5,5	8,2	11,3	7,8	6,4	6,7	7,1	6,7	8,9
k	2,72	2,72	2,72	2,72	2,72	2,72	2,72	2,72	2,72	2,72	2,72	2,72
U	7,31	5,46	5,12	4,85	7,32	10,0	6,95	5,67	5,96	6,28	5,96	7,89
P	356	149	123	104	358	927	307	167	193	226	194	448
f	12,9	1,4	1,7	1,7	4,6	5,4	4,3	7,2	8,4	6,3	13,9	32,0



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

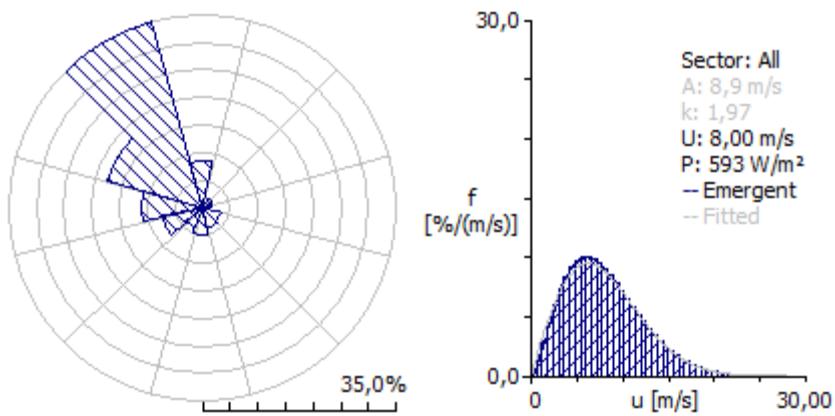


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

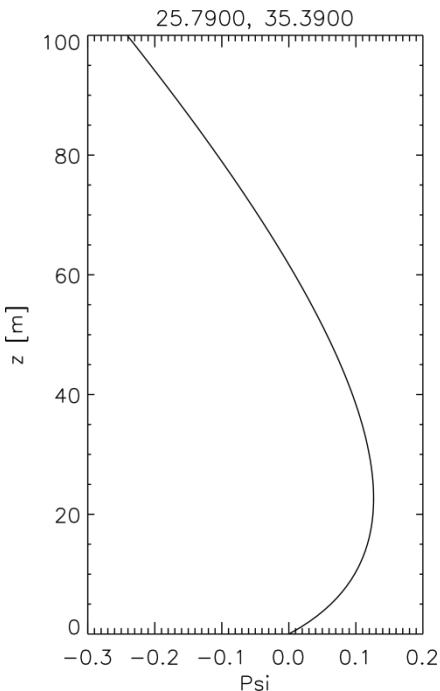
8.4 Anatoliki Kriti II

Site description: 'SAR 35.39N 25.79E GridResolution=0.02'; Position: 35,39°N 25,79°E; Height: 10,00 m a.g.l.

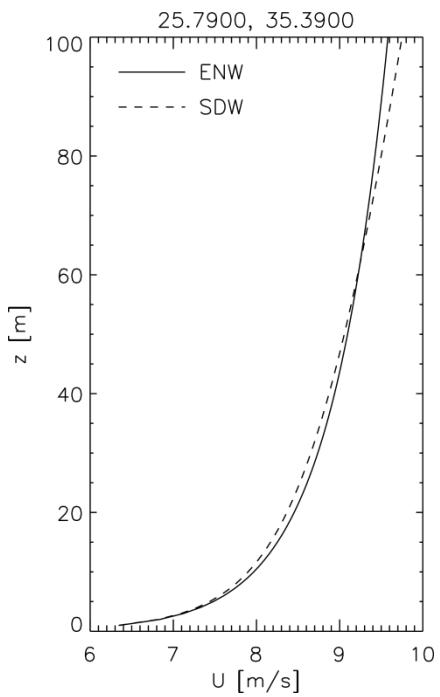
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	8,00	unknown
Mean power density [W/m ²]	unknown	593 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	10,4	3,9	3,8	7,8	6,7	7,7	7,1	6,4	5,0	7,7	8,9	11,4
k	2,43	2,42	2,42	2,43	2,42	2,43	2,43	2,43	2,43	2,43	2,43	2,43
U	9,22	3,44	3,36	6,90	5,96	6,81	6,29	5,70	4,46	6,82	7,91	10,1
P	772	40	37	324	209	312	246	182	87	313	488	101
f	8,6	0,5	2,1	1,7	3,3	3,8	4,8	3,9	7,5	11,1	17,9	34,9



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

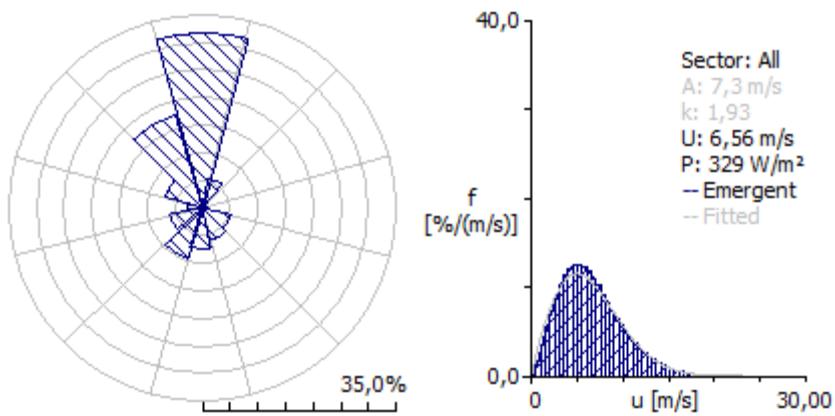


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

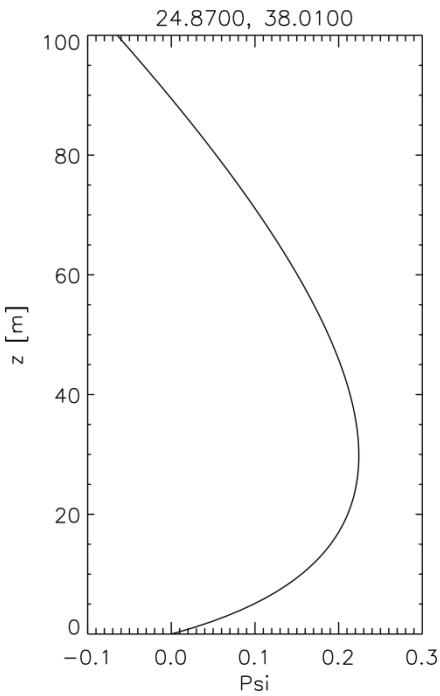
8.5 Andros II

Site description: 'SAR 38.01N 24.87E GridResolution=0.02'; Position: 38,01°N 24,87°E; Height: 10,00 m a.g.l.

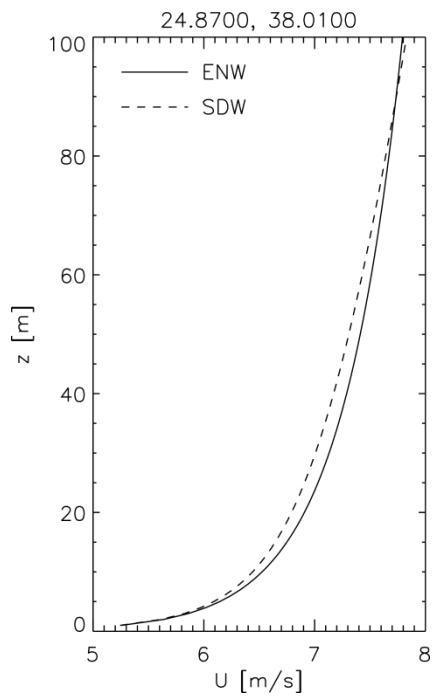
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,56	unknown
Mean power density [W/m ²]	unknown	329 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	9,5	6,8	4,1	2,5	5,0	6,6	5,8	6,2	5,4	4,2	5,9	8,2
k	2,41	2,41	2,41	2,41	2,41	2,41	2,41	2,41	2,41	2,41	2,41	2,41
U	8,45	6,05	3,60	2,26	4,42	5,87	5,14	5,52	4,83	3,75	5,22	7,24
P	600	220	46	11	86	201	135	167	112	52	142	376
f	31,8	5,6	0,7	1,0	5,1	6,0	7,3	9,4	5,9	2,8	6,9	17,4



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

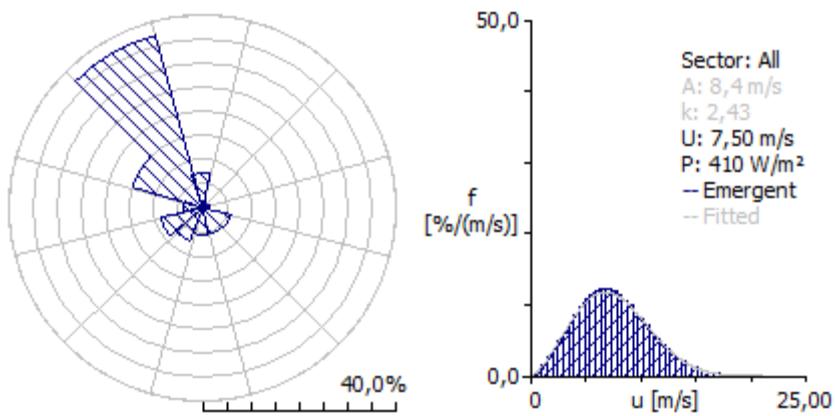


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

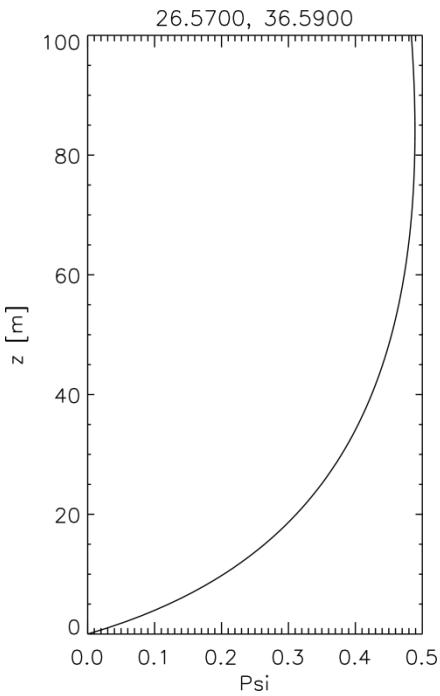
8.6 Astipalaia II

Site description: 'SAR 36.59N 26.57E GridResolution=0.02'; Position: 36,59°N 26,57°E; Height: 10,00 m a.g.l.

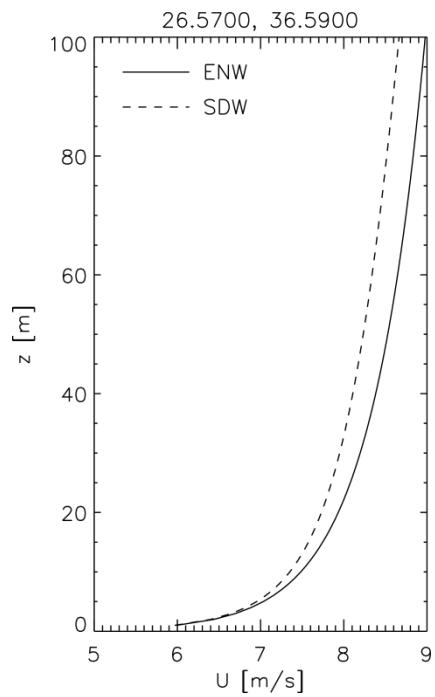
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	7,50	unknown
Mean power density [W/m ²]	unknown	410 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	9,4	7,2	2,4	3,8	8,9	10,7	7,0	7,0	6,6	5,7	7,8	9,6
k	2,85	2,85	2,85	2,85	2,85	2,87	2,85	2,85	2,85	2,85	2,85	2,85
U	8,34	6,39	2,10	3,42	7,90	9,58	6,20	6,22	5,89	5,10	6,94	8,56
P	514	231	8	36	437	776	211	213	181	117	296	556
f	7,4	1,4	1,0	1,3	6,0	5,7	5,4	7,1	8,8	3,8	14,9	37,1



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

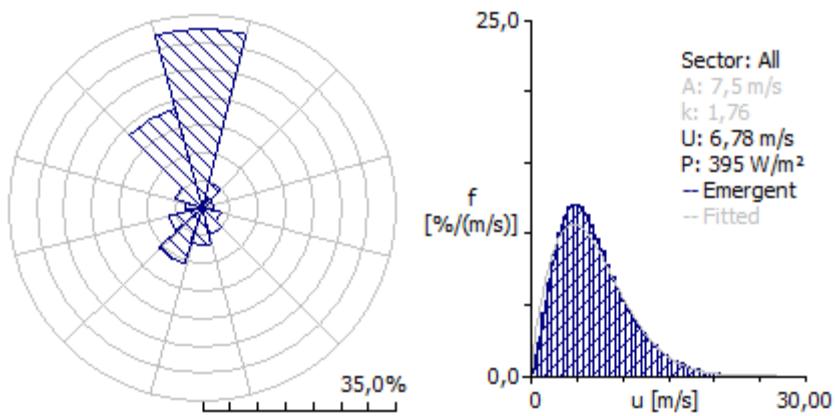


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

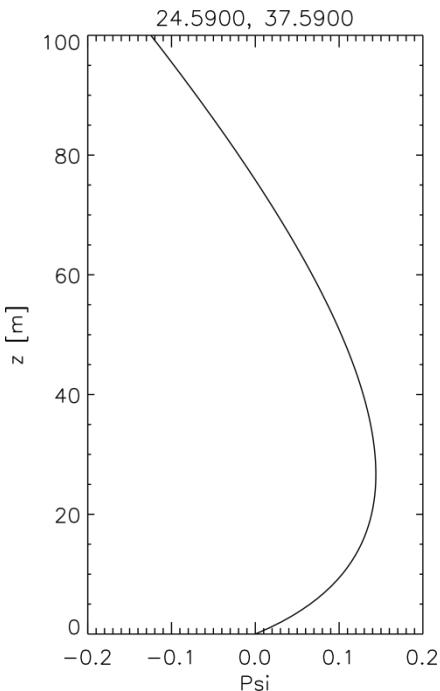
8.7 Gyaros II

Site description: 'SAR 37.59N 24.59E GridResolution=0.02'; Position: 37,59°N 24,59°E; Height: 10,00 m a.g.l.

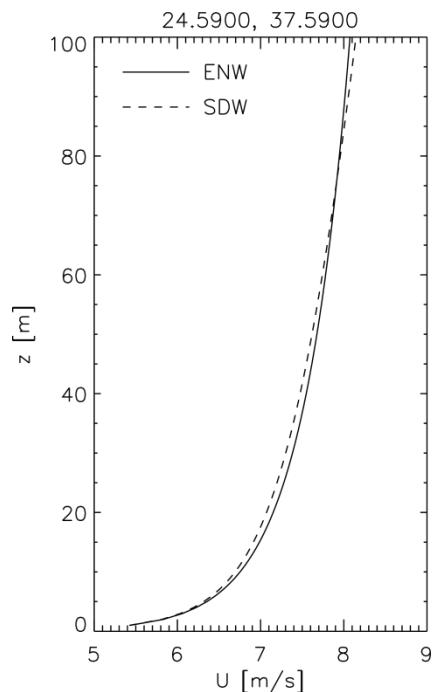
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,78	unknown
Mean power density [W/m ²]	unknown	395 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	10,4	6,1	4,1	4,3	4,8	6,5	4,9	6,4	6,2	5,1	5,7	8,1
k	2,31	2,31	2,31	2,31	2,31	2,30	2,31	2,30	2,31	2,30	2,31	2,31
U	9,18	5,41	3,64	3,78	4,29	5,73	4,33	5,71	5,48	4,54	5,08	7,18
P	794	162	49	56	81	194	83	191	169	96	134	379
f	32,2	4,7	2,0	1,8	3,6	5,0	6,6	10,5	6,4	3,1	5,4	18,6



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

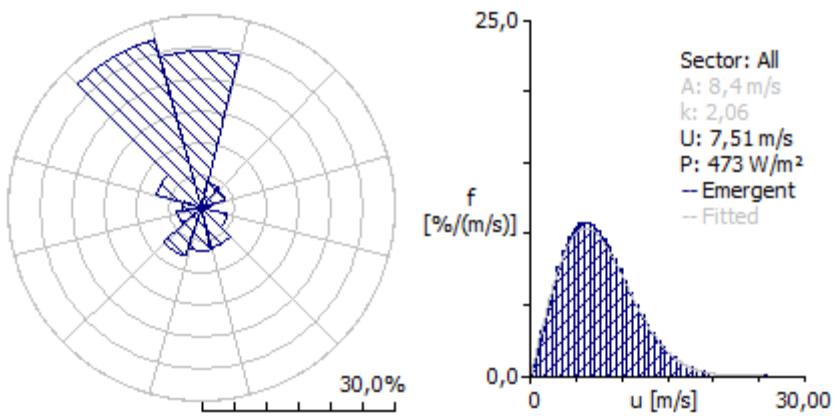


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

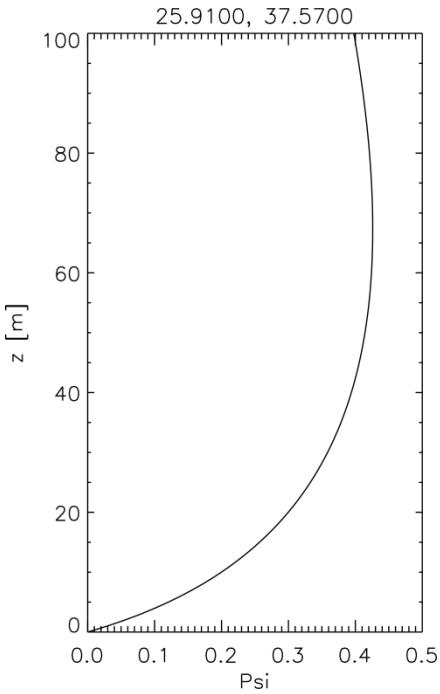
8.8 Ikaria II

Site description: 'SAR 37.57N 25.91E GridResolution=0.02'; Position: 37,57°N 25,91°E; Height: 10,00 m a.g.l.

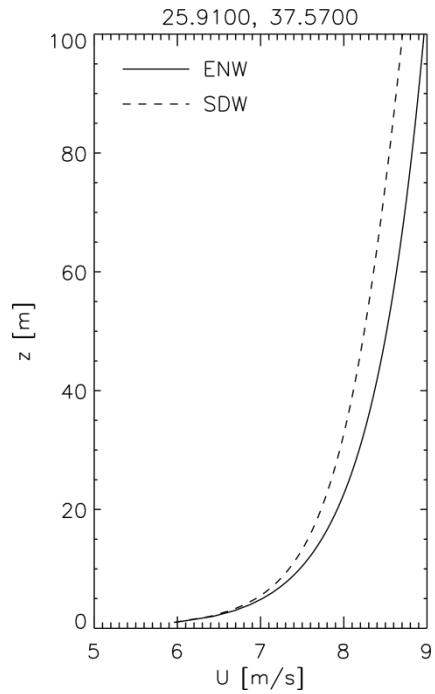
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	7,51	unknown
Mean power density [W/m ²]	unknown	473 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	9,9	8,3	6,1	6,2	9,3	9,7	10,7	8,3	5,4	4,5	7,5	7,9
k	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32	2,32
U	8,81	7,37	5,37	5,52	8,20	8,56	9,52	7,36	4,78	4,03	6,61	7,03
P	699	410	159	172	563	641	881	407	112	67	296	356
f	24,2	4,1	4,0	1,3	4,1	6,3	6,6	7,9	4,0	2,9	7,4	27,2



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

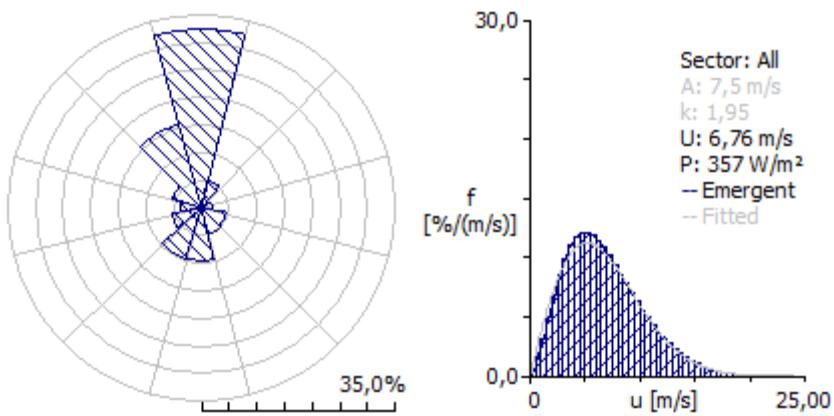


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

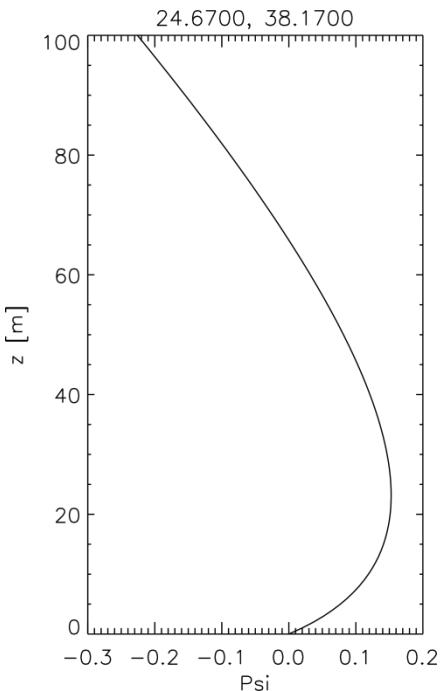
8.9 Kafireas II

Site description: 'SAR 38.17N 24.67E GridResolution=0.02'; Position: 38,17°N 24,67°E; Height: 10,00 m a.g.l.

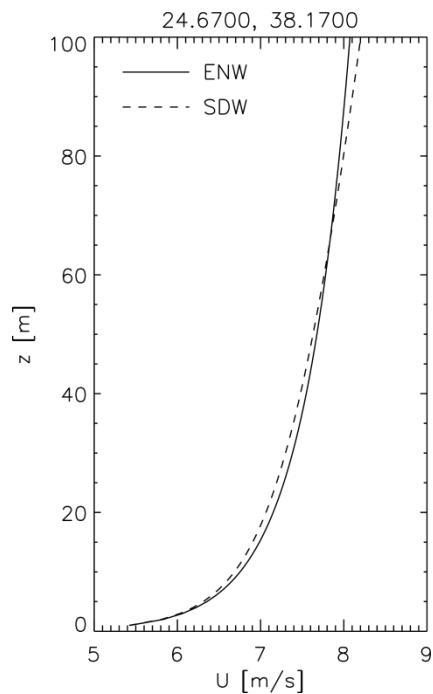
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,76	unknown
Mean power density [W/m ²]	unknown	357 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	9,6	8,2	4,6	3,9	5,7	7,2	6,3	5,8	4,8	3,9	6,6	8,9
k	2,46	2,46	2,46	2,46	2,46	2,46	2,46	2,46	2,46	2,46	2,46	2,46
U	8,51	7,30	4,09	3,46	5,06	6,40	5,59	5,12	4,26	3,48	5,86	7,88
P	603	380	67	41	127	257	171	132	76	41	197	479
f	32,4	5,3	0,9	2,0	4,5	4,8	9,7	9,5	5,6	3,8	5,7	15,8



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

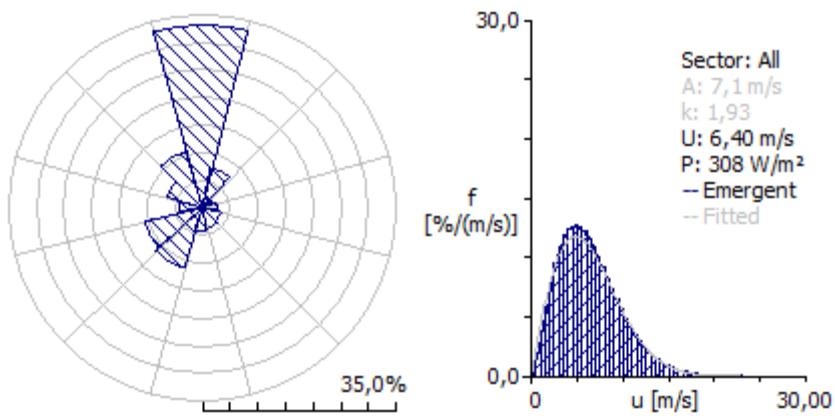


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

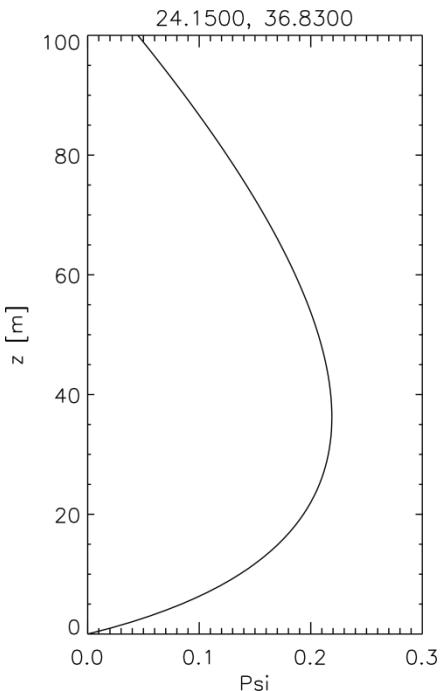
8.10 Milos II

Site description: 'SAR 36.83N 24.15E GridResolution=0.02'; Position: 36,83°N 24,15°E; Height: 10,00 m a.g.l.

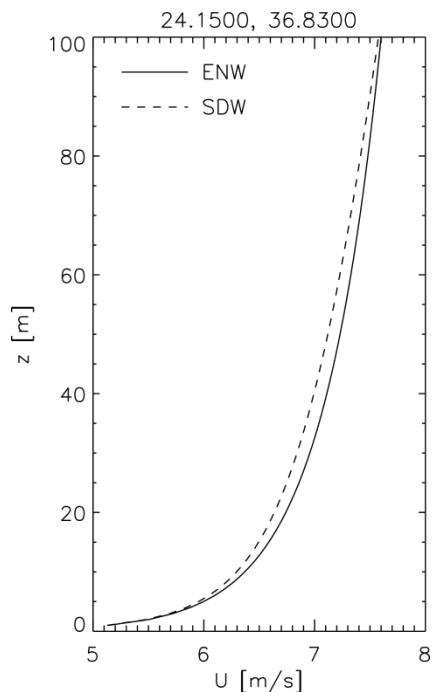
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,40	unknown
Mean power density [W/m ²]	unknown	308 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	9,4	7,1	5,7	4,0	6,6	7,3	5,9	6,4	6,8	3,7	4,7	6,7
k	2,38	2,38	2,38	2,36	2,38	2,38	2,38	2,38	2,38	2,38	2,38	2,38
U	8,29	6,30	5,06	3,56	5,83	6,43	5,23	5,70	6,04	3,27	4,14	5,96
P	572	252	130	46	199	267	143	186	221	35	71	213
f	33,1	7,3	2,1	2,7	3,3	3,7	4,3	11,4	10,5	4,1	6,8	10,7



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

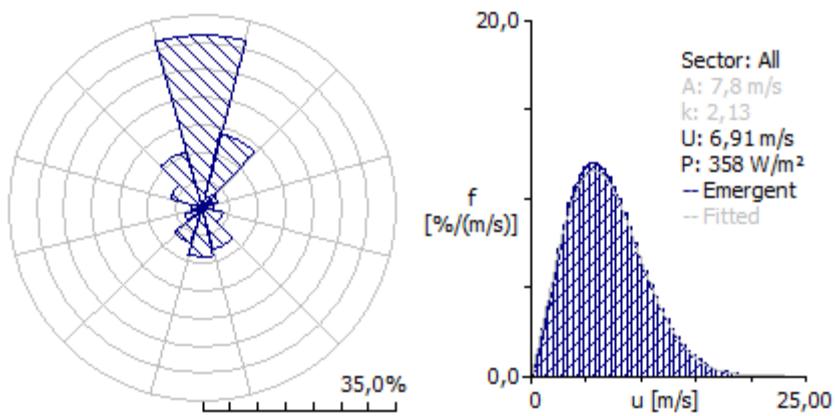


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

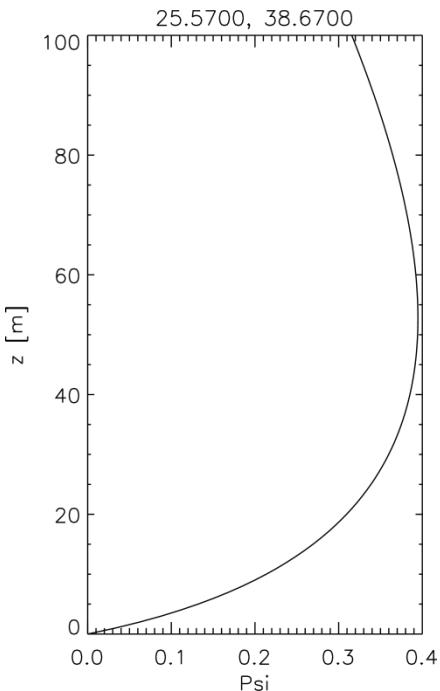
8.11 Psara II

Site description: 'SAR 38.67N 25.57E GridResolution=0.02'; Position: 38,67°N 25,57°E; Height: 10,00 m a.g.l.

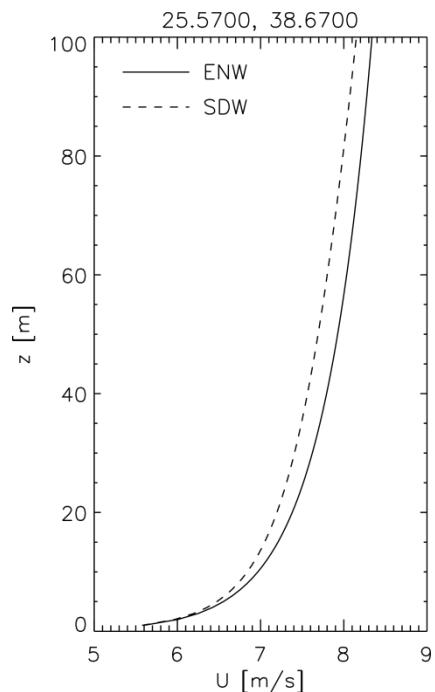
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,91	unknown
Mean power density [W/m ²]	unknown	358 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	8,7	8,7	6,5	5,3	6,6	8,9	8,7	6,9	7,1	5,5	4,9	6,6
k	2,36	2,36	2,36	2,36	2,36	2,36	2,36	2,36	2,36	2,36	2,36	2,36
U	7,70	7,72	5,73	4,68	5,86	7,93	7,70	6,15	6,31	4,84	4,36	5,84
P	460	464	190	103	203	502	459	235	253	114	84	201
f	31,3	13,9	2,9	2,0	3,7	7,7	9,0	6,8	3,6	2,1	6,1	10,8



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

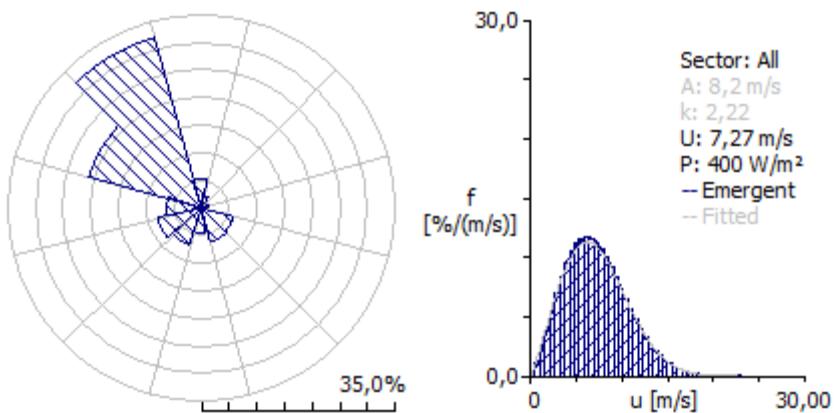


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

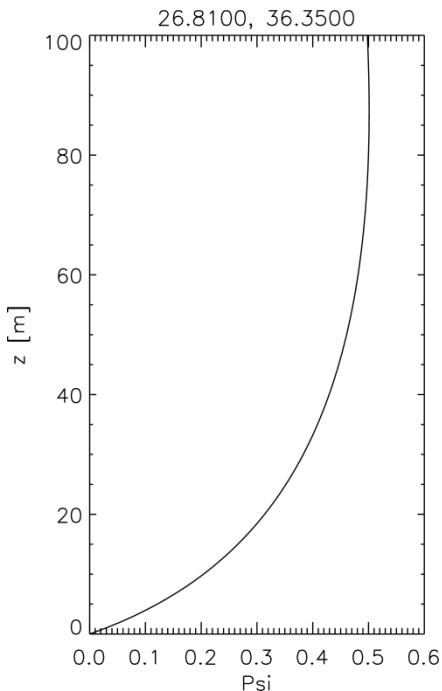
8.12 Sirna II

Site description: 'SAR 36.35N 26.81E GridResolution=0.02'; Position: 36,35°N 26,81°E; Height: 10,00 m a.g.l.

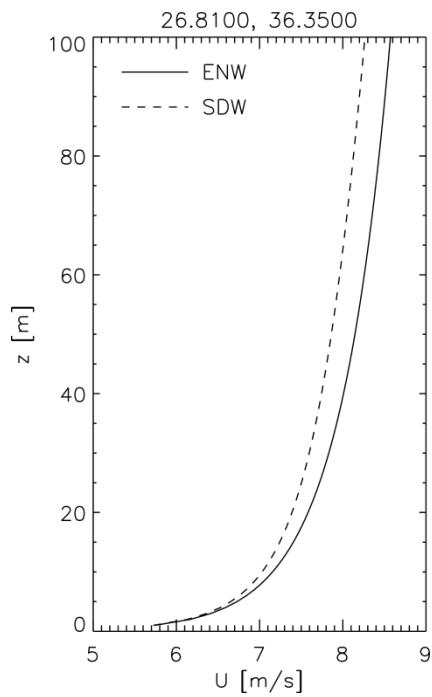
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	7,27	unknown
Mean power density [W/m ²]	unknown	400 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	9,9	3,5	3,7	5,3	8,3	10,9	5,7	7,1	7,8	5,4	7,7	9,4
k	2,62	2,61	2,61	2,61	2,62	2,62	2,62	2,62	2,62	2,61	2,62	2,62
U	8,76	3,10	3,26	4,75	7,34	9,71	5,03	6,31	6,96	4,77	6,87	8,32
P	629	28	32	101	370	856	119	235	315	102	303	539
f	5,2	2,3	0,3	1,1	5,8	6,4	4,6	7,2	8,0	6,2	21,1	31,9



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

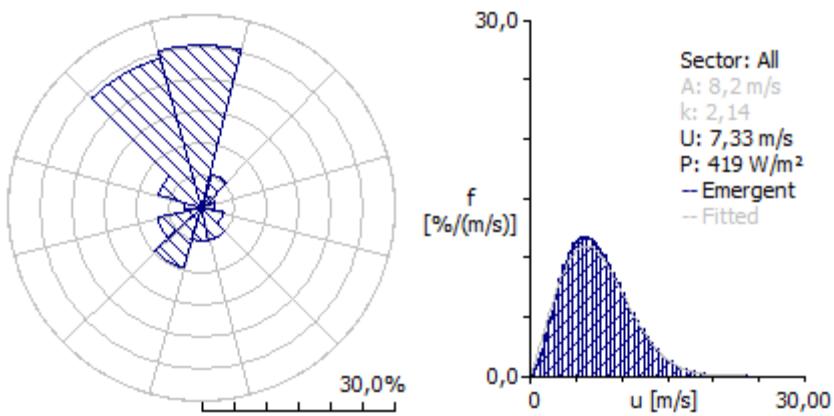


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

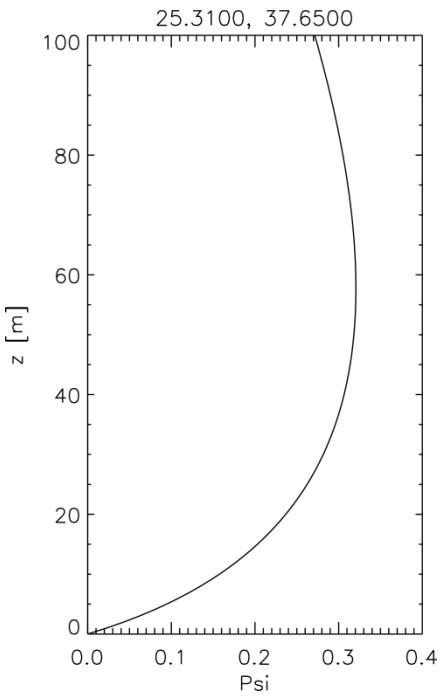
8.13 Tinos II

Site description: 'SAR 37.65N 25.31E GridResolution=0.02'; Position: 37,65°N 25,31°E; Height: 10,00 m a.g.l.

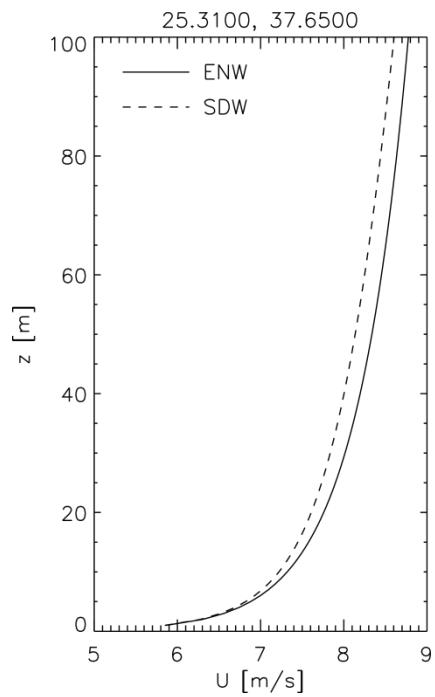
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	7,33	unknown
Mean power density [W/m ²]	unknown	419 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	10,7	7,8	6,6	4,2	7,4	8,4	8,0	7,2	5,3	4,3	6,3	8,8
k	2,67	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66	2,66
U	9,52	6,90	5,82	3,72	6,61	7,48	7,08	6,36	4,68	3,82	5,58	7,78
P	797	303	183	48	268	387	328	238	95	52	160	436
f	25,4	5,6	2,4	2,0	3,6	5,1	5,2	9,8	7,1	2,6	7,1	24,1



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.

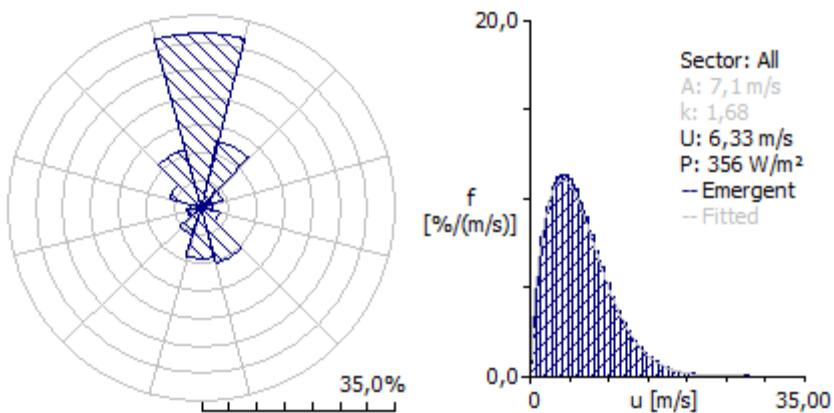


Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

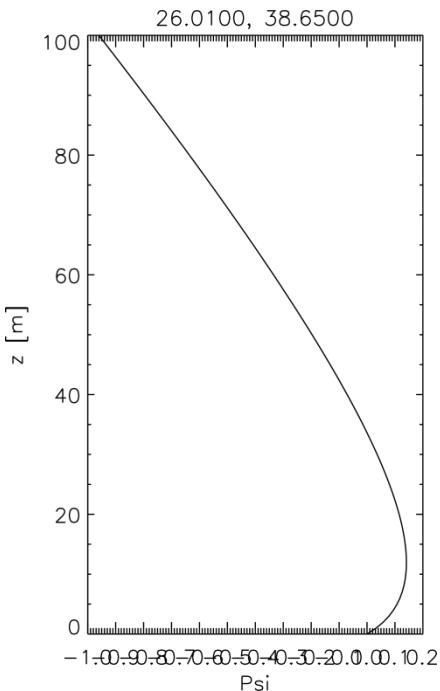
8.14 Xios II

Site description: 'SAR 38.65N 26.01E GridResolution=0.02'; Position: 38,65°N 26,01°E; Height: 10,00 m a.g.l.

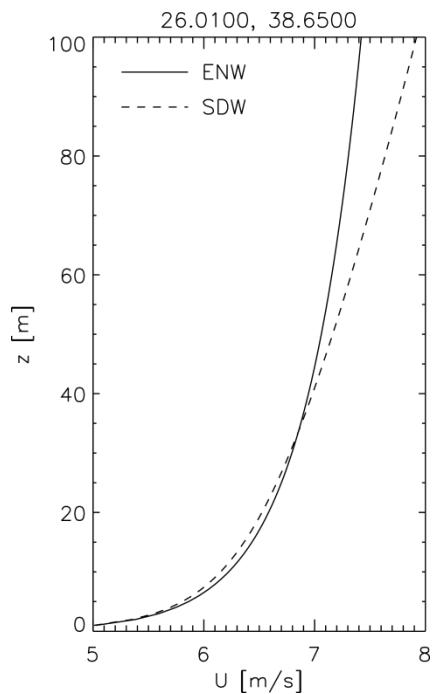
Parameter	Measured	Emergent	Discrepancy
Mean wind speed [m/s]	unknown	6,33	unknown
Mean power density [W/m ²]	unknown	356 W/m ²	unknown



	0	30	60	90	120	150	180	210	240	270	300	330
A	7,2	8,1	6,4	4,9	7,1	7,7	9,1	5,2	5,9	5,6	7,0	5,9
k	1,79	1,79	1,79	1,79	1,79	1,79	1,79	1,79	1,79	1,79	1,79	1,79
U	6,36	7,18	5,72	4,39	6,29	6,89	8,10	4,65	5,26	4,98	6,23	5,22
P	341	489	248	112	329	432	702	132	192	163	320	188
f	31,7	12,4	4,0	2,0	3,5	10,2	9,3	5,3	2,7	1,9	6,0	10,9



Profile of the long-term stability correction, ψ from 0 m to 100 m calculated from WRF data. Positive ψ -values indicate unstable conditions whereas negative ψ -values indicate stable conditions in the atmosphere.



Mean wind profiles from 0 m to 100 m calculated from the combined SAR and WRF data set. Stability Dependent Winds (SDW) are calculated with a correction for atmospheric stability (i.e. the ψ -profile above) whereas Equivalent Neutral Winds (ENW) are calculated without the stability correction parameter. The difference between the two plots shows the effect of including stability information in the wind profile description.

9. References

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