Risø National Laboratory

Satellite SAR applied in offshore wind ressource mapping:

possibilities and limitations

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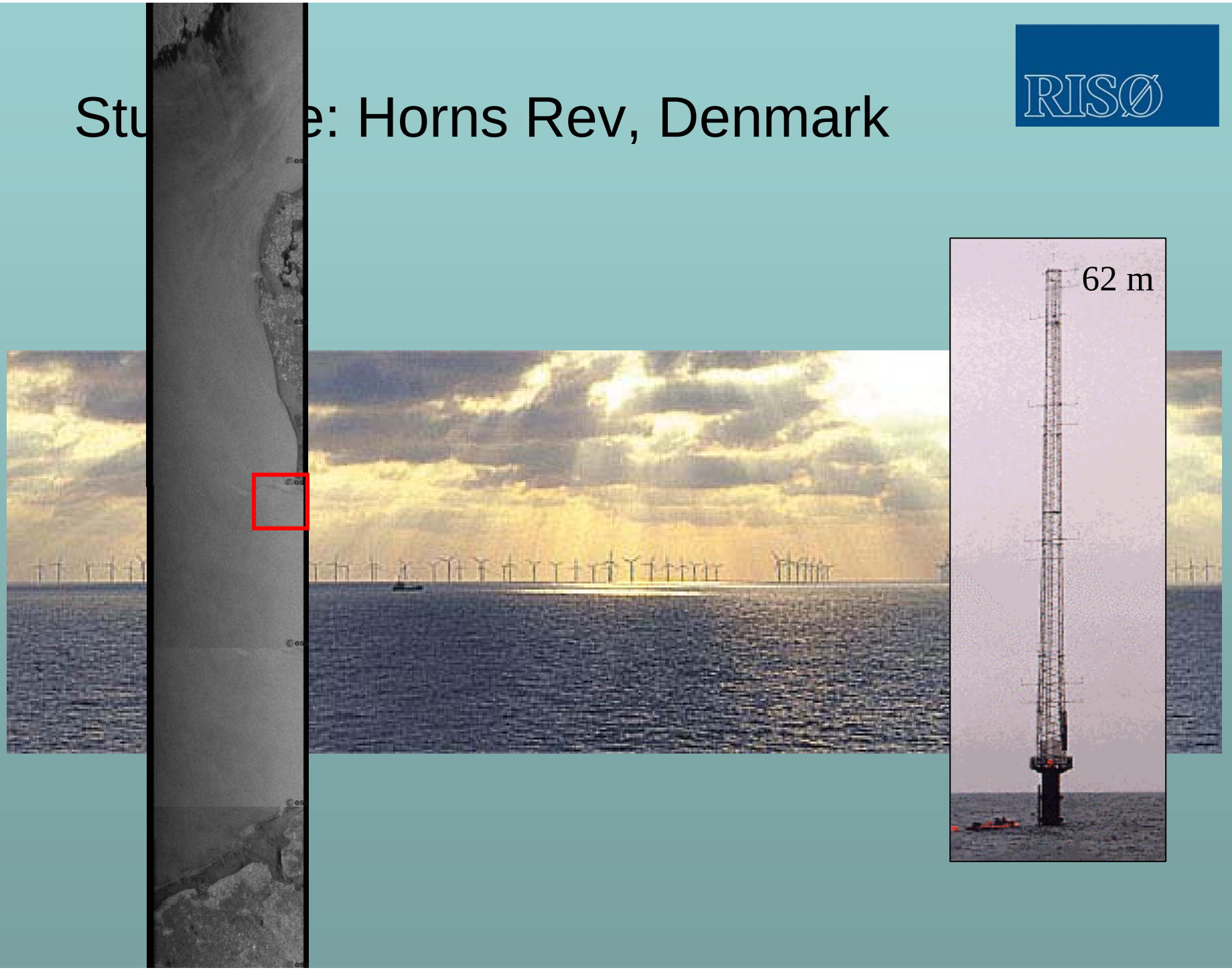
Wind from SAR

- The objective is to quantify the regional offshore wind climate for wind energy application based on satellite SAR

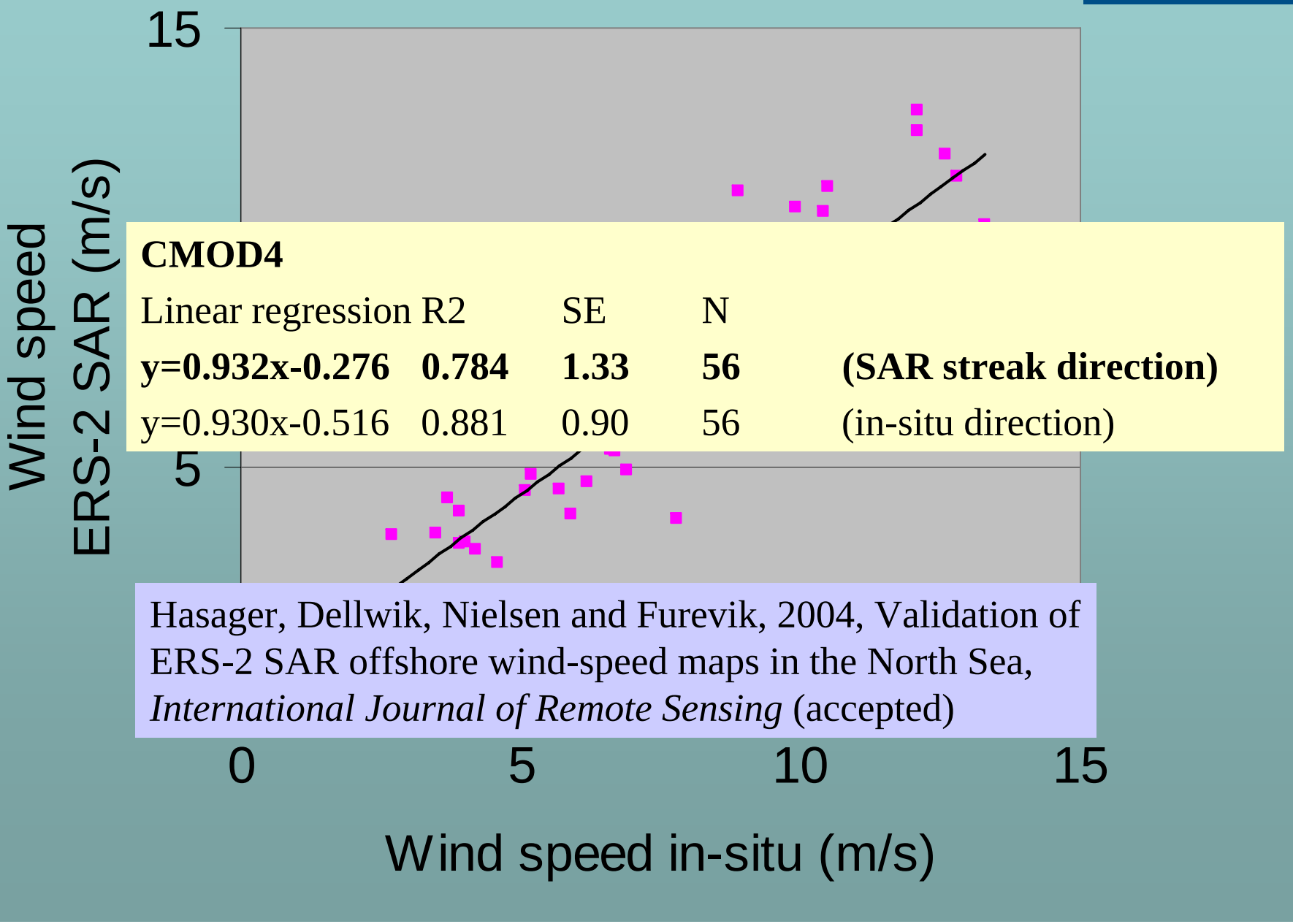
- Study of 85 ERS-2 SAR scenes

- Using CMOD4 (Stoffelen and Anderson, 1997)

Stu e: Horns Rev, Denmark



Horns Rev in the North Sea

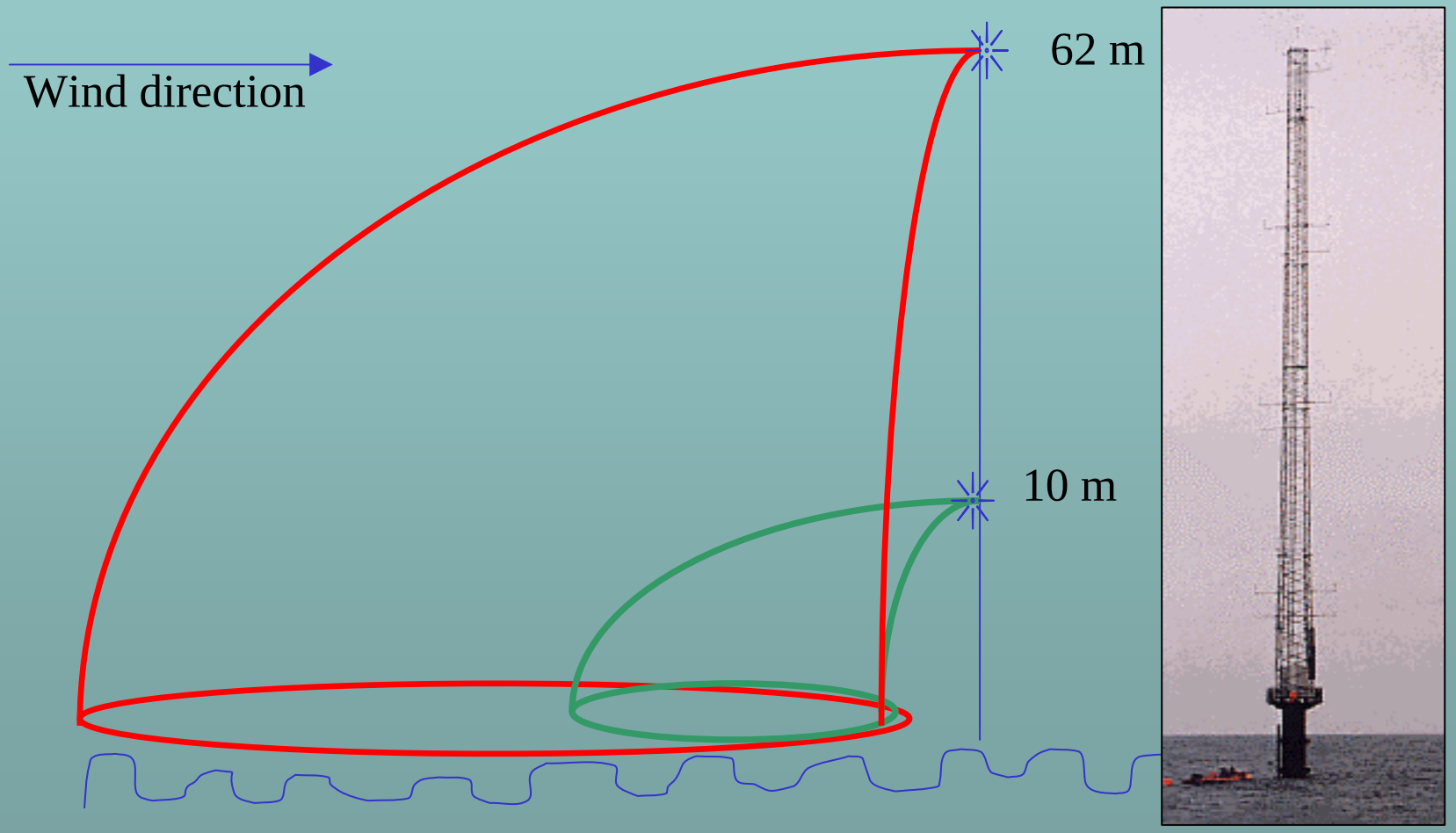


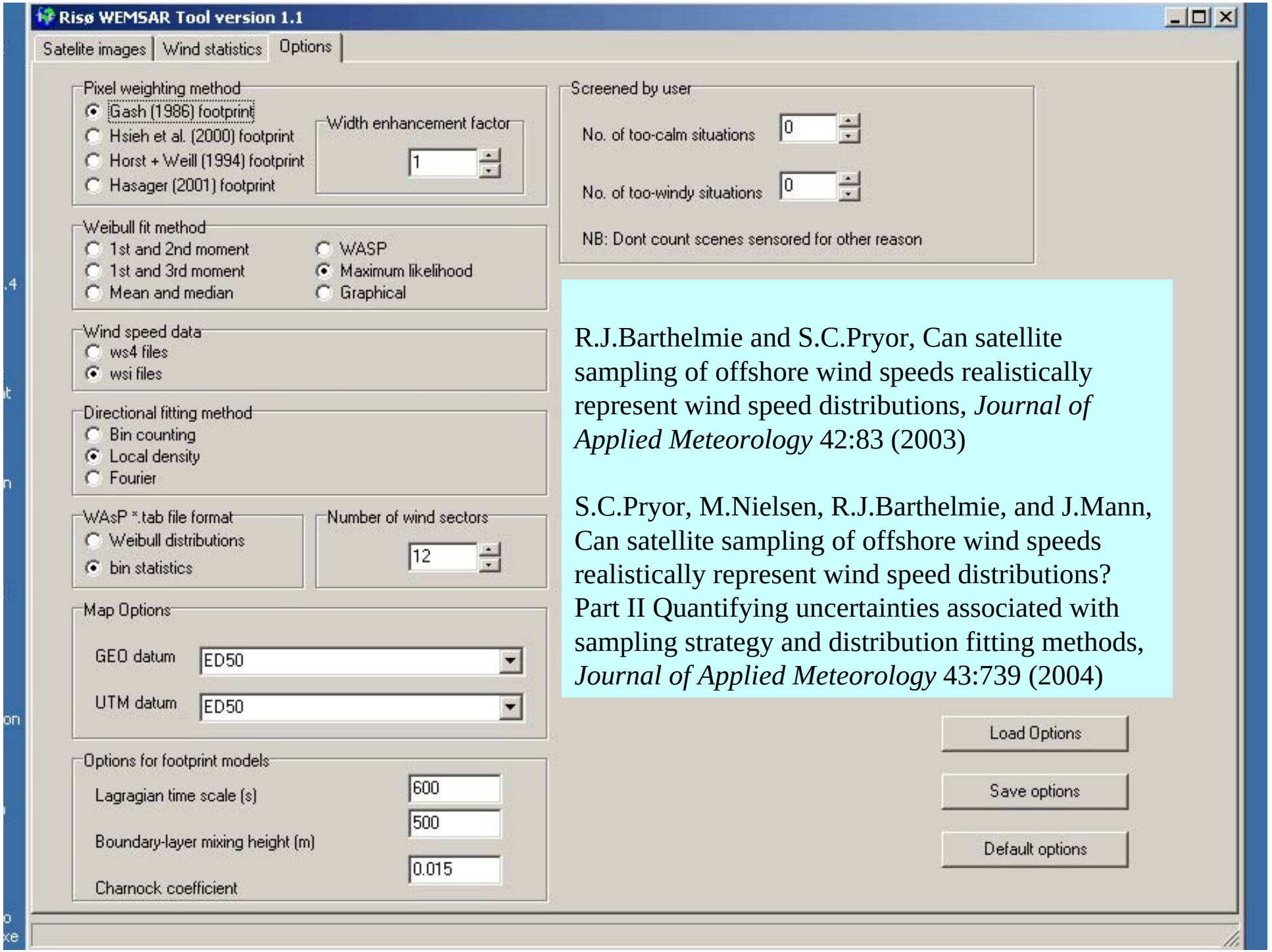
CMOD4

Linear regression	R2	SE	N	
y=0.932x-0.276	**0.784**	**1.33**	**56**	**(SAR streak direction)**
y=0.930x-0.516	0.881	0.90	56	(in-situ direction)

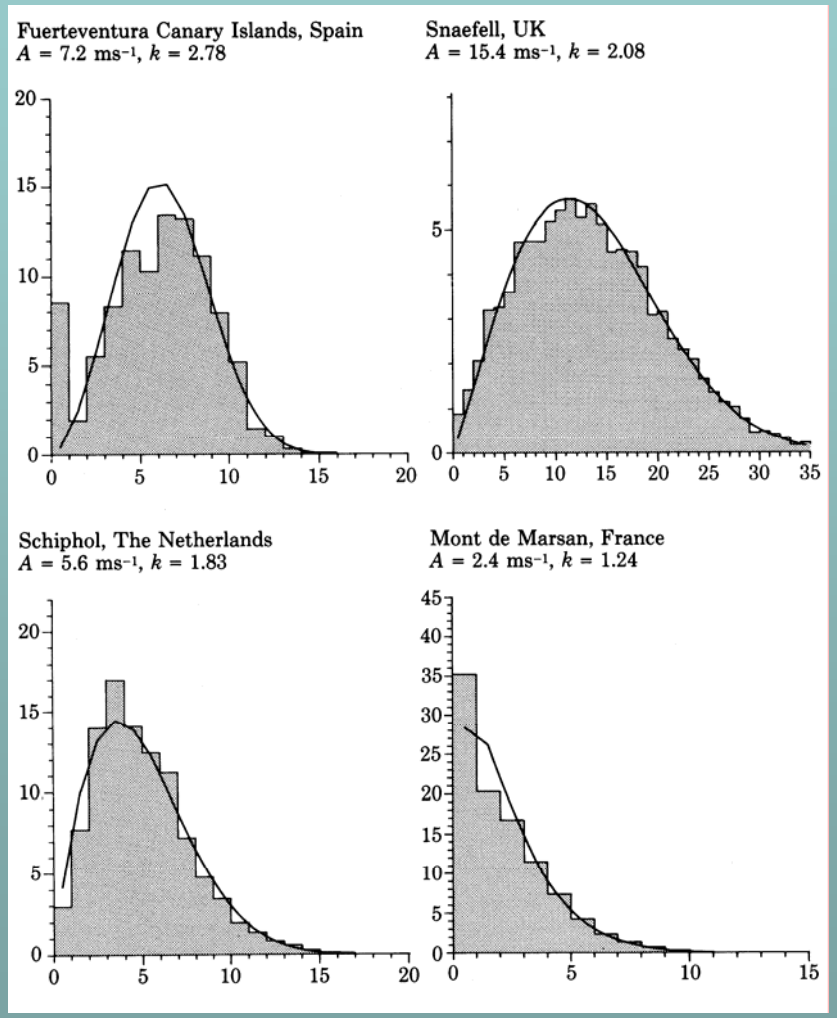
Hasager, Dellwik, Nielsen and Furevik, 2004, Validation of ERS-2 SAR offshore wind-speed maps in the North Sea, *International Journal of Remote Sensing* (accepted)

Upwind footprints for the Horns Rev mast




Risø WEMSAR Tool version 1.1
Satelite images
Wind statistics
Options
Pixel weighting method
Gash (1986) footprint
Hsieh et al. (2000) footprint
Horst + Weill (1994) footprint
Hasager (2001) footprint
Width enhancement factor
1
Weibull fit method
1st and 2nd moment
1st and 3rd moment
Mean and median
WASP
Maximum likelihood
Graphical
Wind speed data
ws4 files
wsi files
Directional fitting method
Bin counting
Local density
Fourier
WAsP *.tab file format
Weibull distributions
bin statistics
Number of wind sectors
12
Map Options
GEO datum
ED50
UTM datum
ED50
Options for footprint models
Lagragian time scale (s)
600
Boundary-layer mixing height (m)
500
Charnock coefficient
0.015
Screened by user
No. of too-calm situations
0
No. of too-windy situations
0
NB: Dont count scenes sensored for other reason
R.J.Barthelmie and S.C.Pryor, Can satellite sampling of offshore wind speeds realistically represent wind speed distributions, Journal of Applied Meteorology 42:83 (2003)
S.C.Pryor, M.Nielsen, R.J.Barthelmie, and J.Mann, Can satellite sampling of offshore wind speeds realistically represent wind speed distributions? Part II Quantifying uncertainties associated with sampling strategy and distribution fitting methods, Journal of Applied Meteorology 43:739 (2004)
Load Options
Save options
Default options

Weibull distributions



Weibull distribution:

$$f(u) = \frac{k}{A}\left(\frac{u}{A}\right)^{k-1} \mathrm{Exp}\left(-\left(\frac{u}{A}\right)^{k}\right)$$

f: frequency of occurrence
u: wind speed
k: shape parameter
A: scale parameter

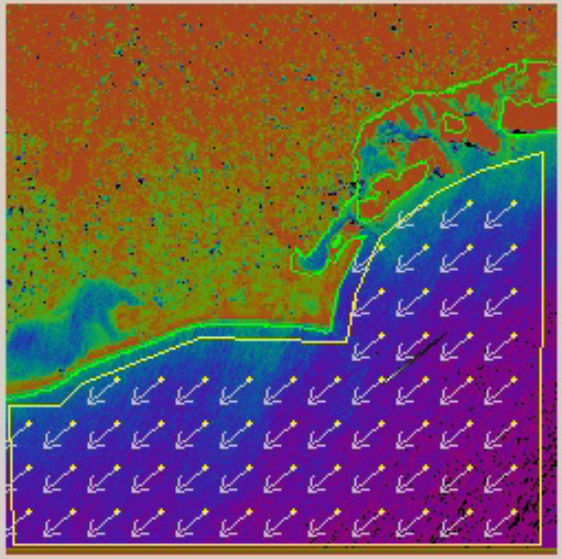
Risø WEMSAR Tool version 1.1

Satelite images | Wind statistics | Options

Selected scene

ERS-2 SAR
DATE: 20011023
TIME: 102646
ORBIT: 34030
FRAME: 2482
CORNER COORDINATES:
(row,col) : lat,lon
(0,0) : 55.9494 , 9.2078
(253,0) : 55.0685 , 8.8102
(253,250) : 55.2756 , 7.2846
(0,250) : 56.1593 , 7.6462
PIXEL SIZE: 400m x 400m
UTM 32
(row,col) : East North
(0,0) : 512978 6200604
(253,0) : 487879 6102563
(253,250) : 391022 6126935
(0,250) : 415913 6224772

Field



Selected site

Latitude: 55.5077
Longitude: 7.8750
Turbine hub height (m): 65

Show stream ☑
Show boundary ☑
Show footprint ☑
Show coast ☑

Displayed field
- none
- ◉ wind speed
- wind direction

Footprint contour (%): 5

List of satelite scenes

- ☑ 31024_2482_010327
- ☑ 31296_2482_010415
- ☑ 31360_1107_010419
- ☑ 31525_2482_010501
- ☑ 32026_2482_010605
- ☑ 32799_2482_010729
- ☑ 32820_1107_010730
- ☑ 33028_2482_010814
- ☑ 33092_1107_010818
- ☑ 33300_2482_010902
- ☑ 33364_1107_010906
- ☑ 33529_2482_010918
- ☑ 33822_1107_011008
- ☑ 34030_2482_011023

Select all | Select none

Boundary

442992 6217618
440710 6208705
443601 6203863
446298 6180520
439569 6157462
438974 6155137
446730 6151557
455635 6144393
461209 6132288
462620 6123280
462948 6111656
394813 6129445
418821 6223224

Max Boundary | Save Boundary

List of scenes using all data within boundary

- ☐ 21340_1107_990520
- ☐ 21777_2482_990620
- ☐ 21798_1107_990621
- ☐ 22006_2486_990706
- ☐ 22070_1107_990710
- ☐ 22342_1107_990729
- ☐ 22507_2493_990810
- ☐ 22800_1107_990830
- ☐ 23072_1107_990918
- ☐ 23280_2493_991003
- ☐ 23344_1107_991007
- ☐ 23509_2493_991019
- ☐ 24010_2493_991123
- ☐ 24160_1107_991203

Speed = 12.77m/s Direction = 156.0 Deg @UTM 438.645E, 6134.234N

Risø WEMSAR Tool version 1.1

Satelite images | Wind statistics | Options

Scene	Speed	Direction	Heading
21340_1107_990520	3.33	123.7	347.7
21777_2482_990620	9.59	222.6	195.0
21798_1107_990621	9.57	315.1	346.6
22006_2486_990706	3.75	297.8	194.4
22070_1107_990710	2.05	72.8	347.1
22342_1107_990729	6.17	33.6	347.7
22507_2493_990810	9.87	328.9	194.5
22800_1107_990830	7.70	292.8	346.6
23072_1107_990918	4.34	95.8	347.1
23280_2493_991003	N/A	N/A	195.1
23344_1107_991007	10.13	275.4	347.7
23509_2493_991019	9.80	88.4	194.5
24010_2493_991123	0.97	232.1	194.5
24160_1107_991203	N/A	N/A	344.6
24346_1107_991216	11.63	244.8	347.7
24783_2493_000116	N/A	N/A	195.1

WASP observed wind data file (*.tab)

35.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Save

Report

Directional fit:	Local density	
Wind speed data:	wsi files	
Number of wind sectors:	12	
Lagragian time scale (s)	600	
Boundary-layer mixing height (m)		500
Charnock coefficient	0.015	

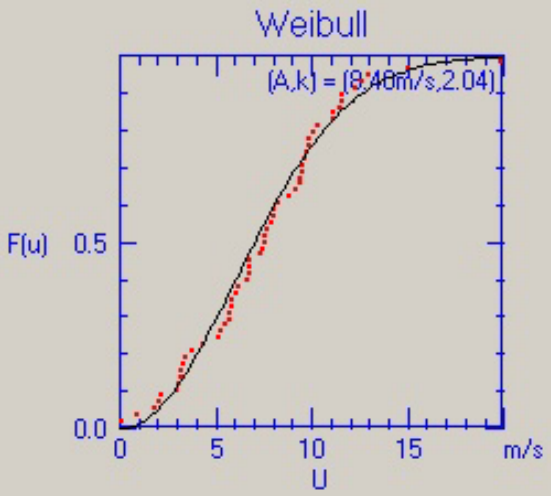
Save Report

Save Graphs

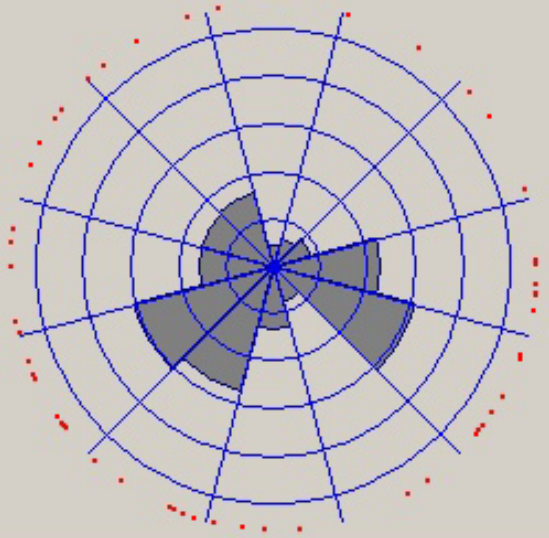
Total windspeed distribution

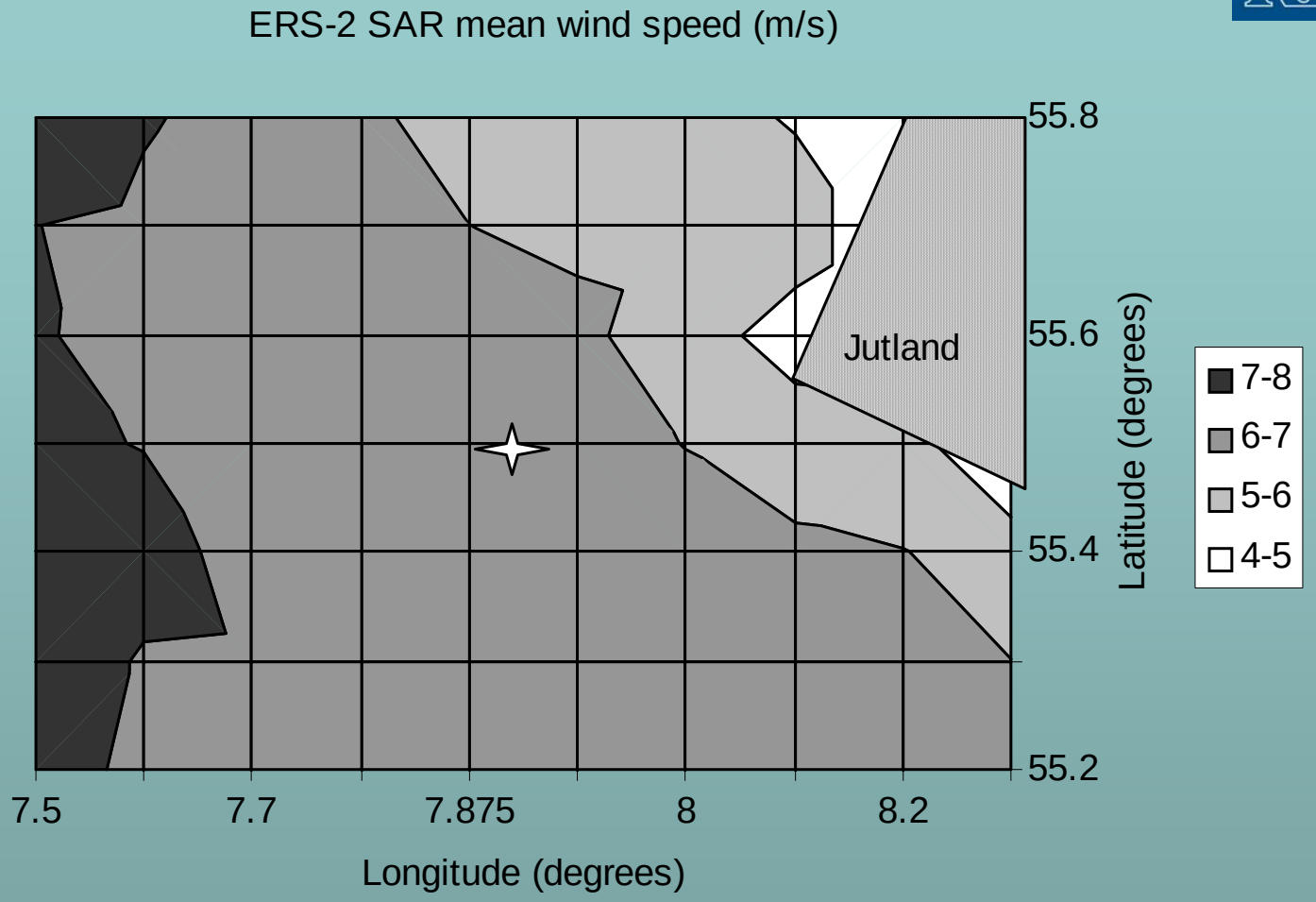
	Estimate	Uncertainty
Mean wind	7.44	0.72
Energy density	772.70	47.80
Skewness	0.61	13.12
Kurtosis	3.20	1.73
Weibull k	2.04	0.31
Weibull A	8.40	0.84

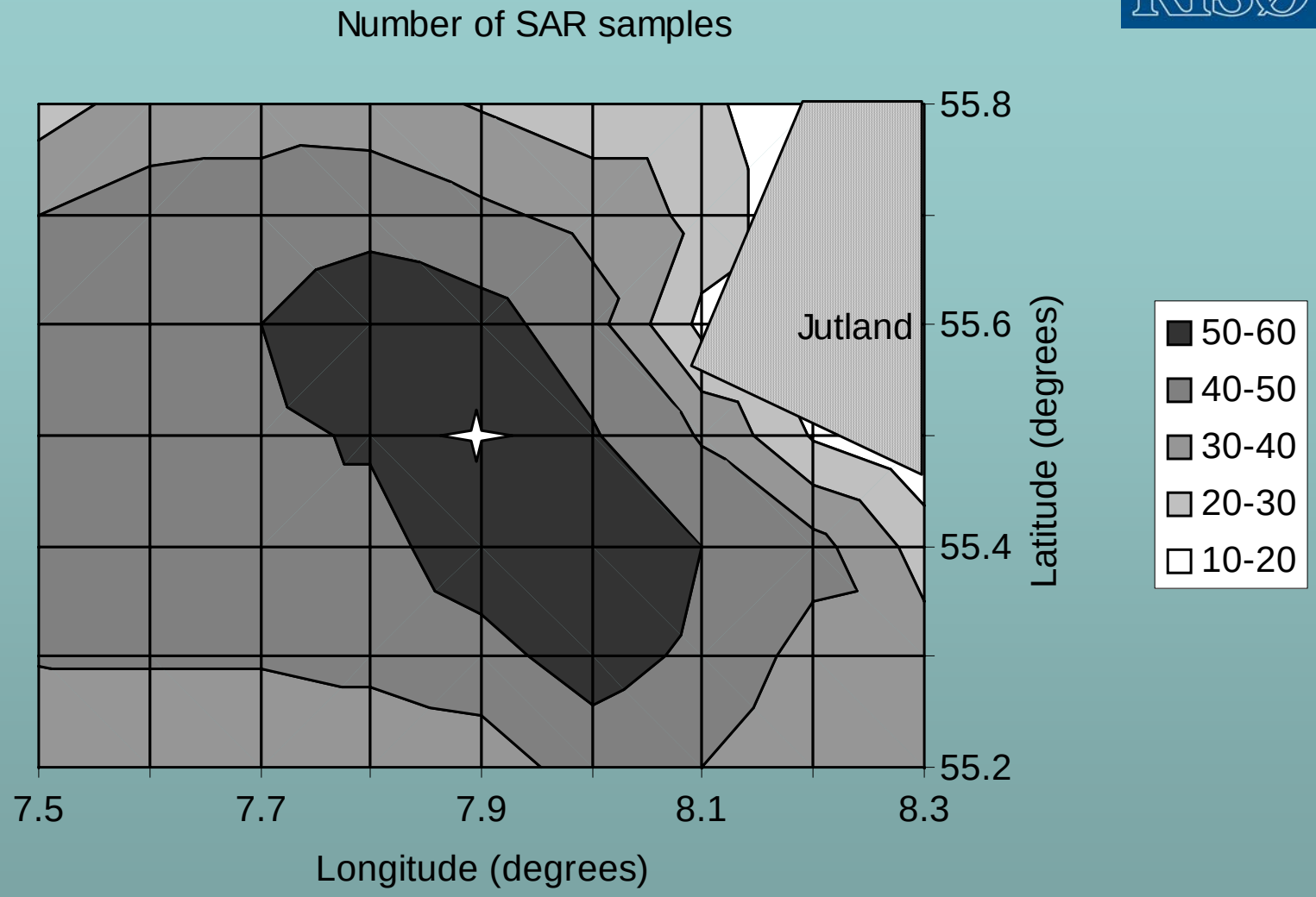
No. of samples 57

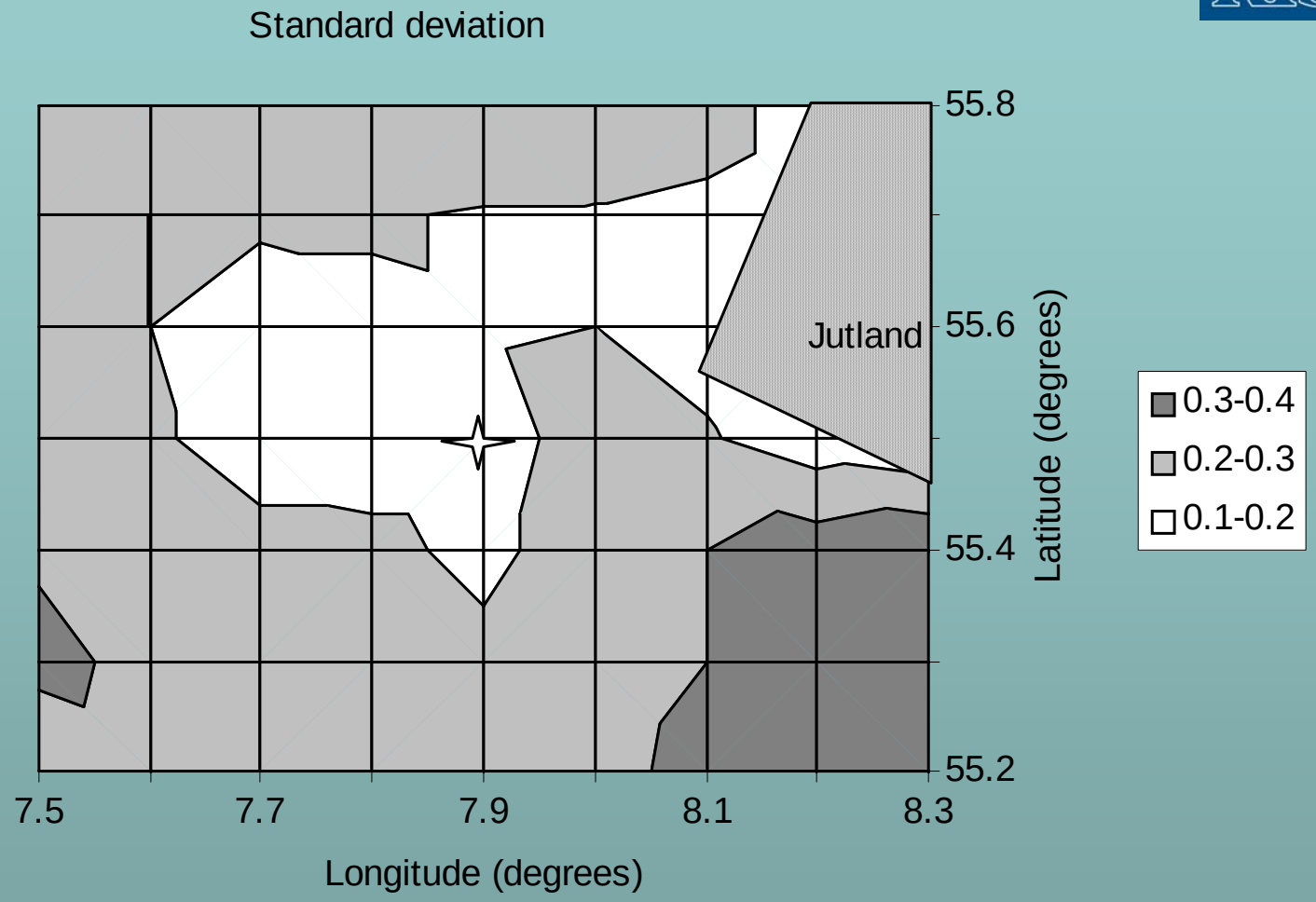


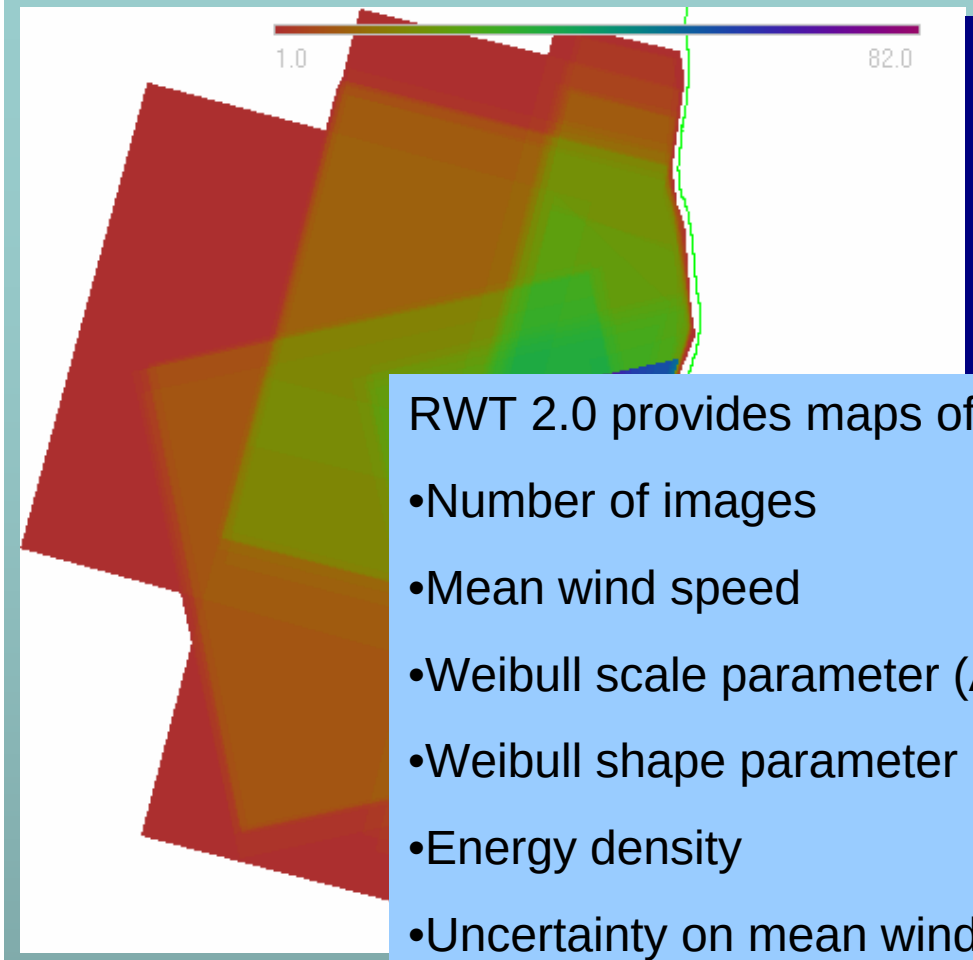
Directional distribution

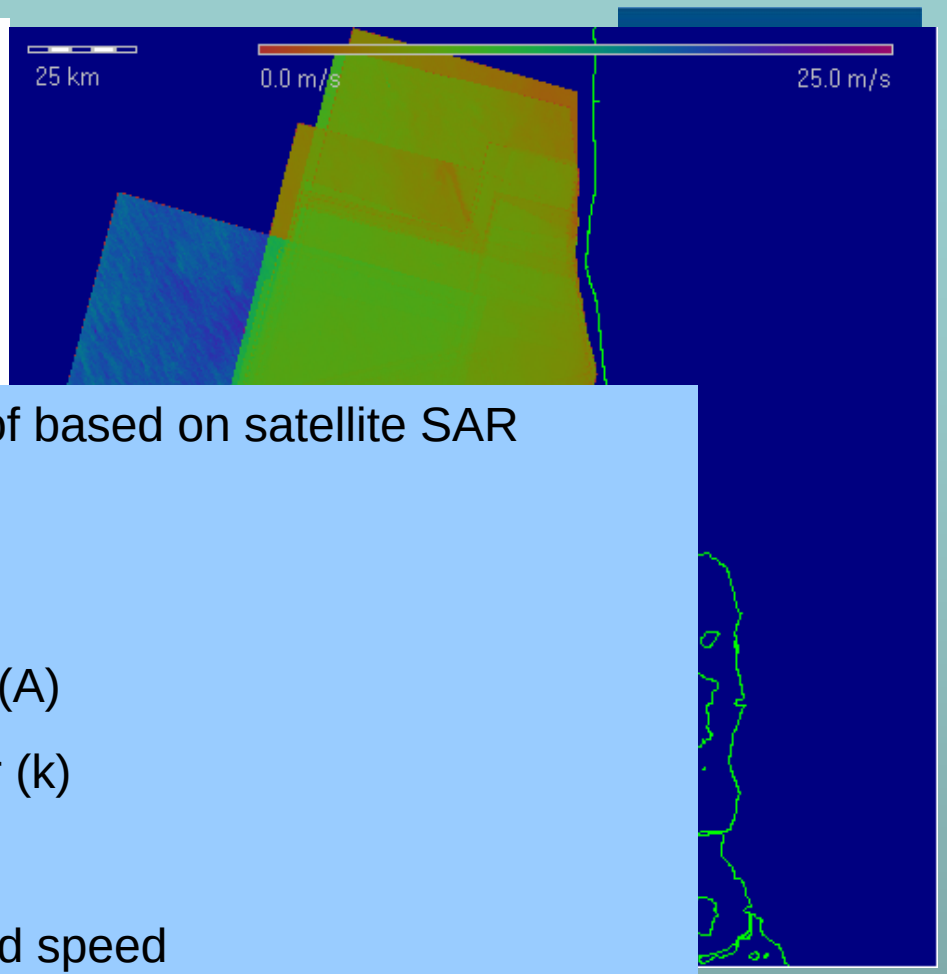



ERS-2 SAR mean wind speed (m/s)
Jutland
55.8
55.6
55.4
55.2
Latitude (degrees)
7-8
6-7
5-6
4-5
7.5
7.7
7.875
8
8.2
Longitude (degrees)


Number of SAR samples
Jutland
55.8
55.6
55.4
55.2
Latitude (degrees)
7.5
7.7
7.9
8.1
8.3
Longitude (degrees)
50-60
40-50
30-40
20-30
10-20


Standard deviation
55.8
55.6
55.4
55.2
Jutland
Latitude (degrees)
0.3-0.4
0.2-0.3
0.1-0.2
7.5
7.7
7.9
8.1
8.3
Longitude (degrees)

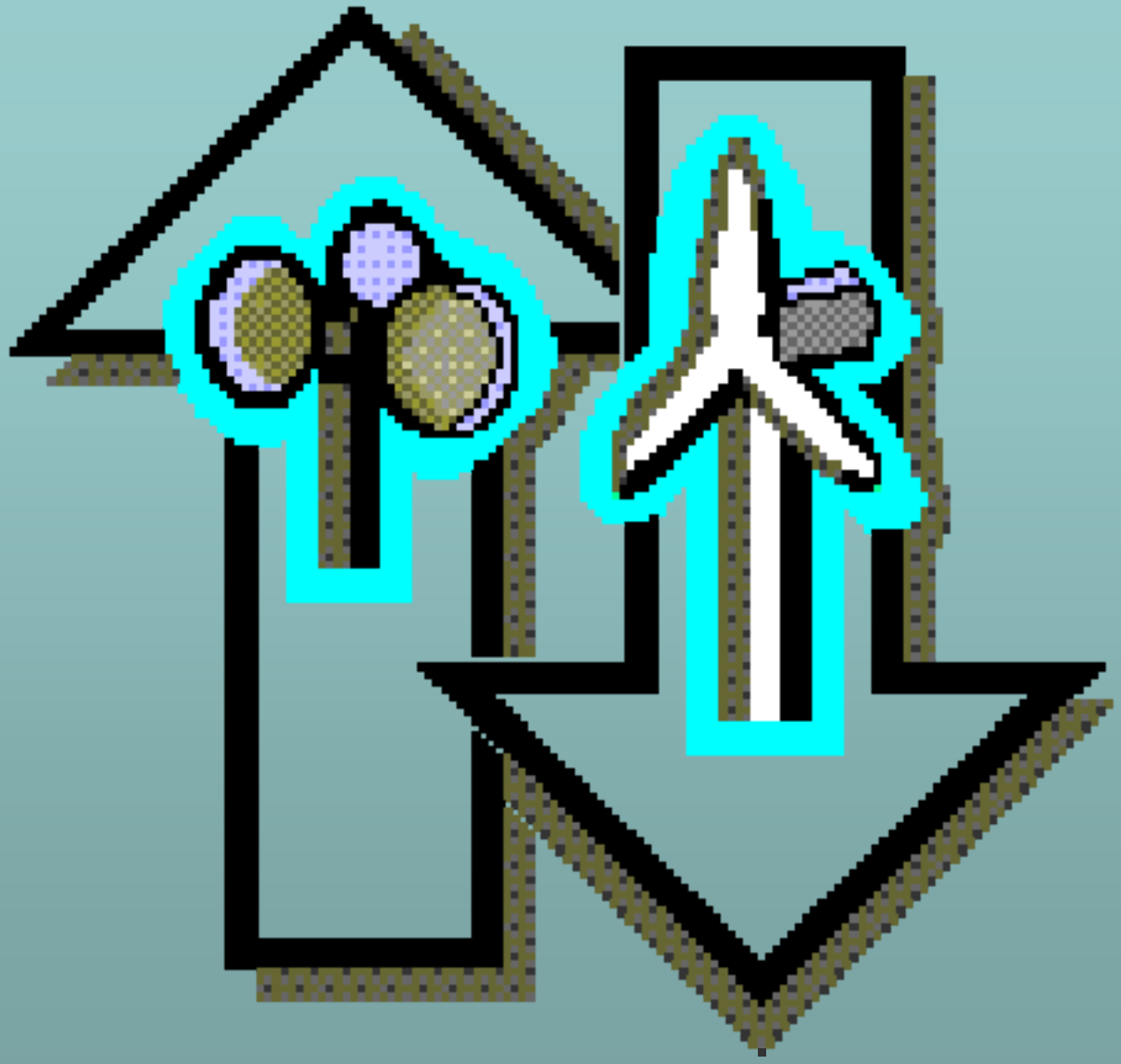




RWT 2.0 provides maps of based on satellite SAR

- Number of images
- Mean wind speed
- Weibull scale parameter (A)
- Weibull shape parameter (k)
- Energy density
- Uncertainty on mean wind speed
- Uncertainty on energy density

- PLUS
- Wind rose
- Tab-file for WA^{S}P



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WAsP - the Wind Atlas Analysis and Application Program

Acknowledgements

Funding

STVF	SAR-WAKE project (2003-2004)
STVF	SAT-WIND project (2004-2005)
ESA EOMD	EO-WINDFARM (2003-2006)
EU	WEMSAR (2000-2003)

Data:

ESA EO-1356 and AO-153 for satellite data

Elsam Engineering for meteorological data