Using satellite data for mapping offshore wind resources and wakes

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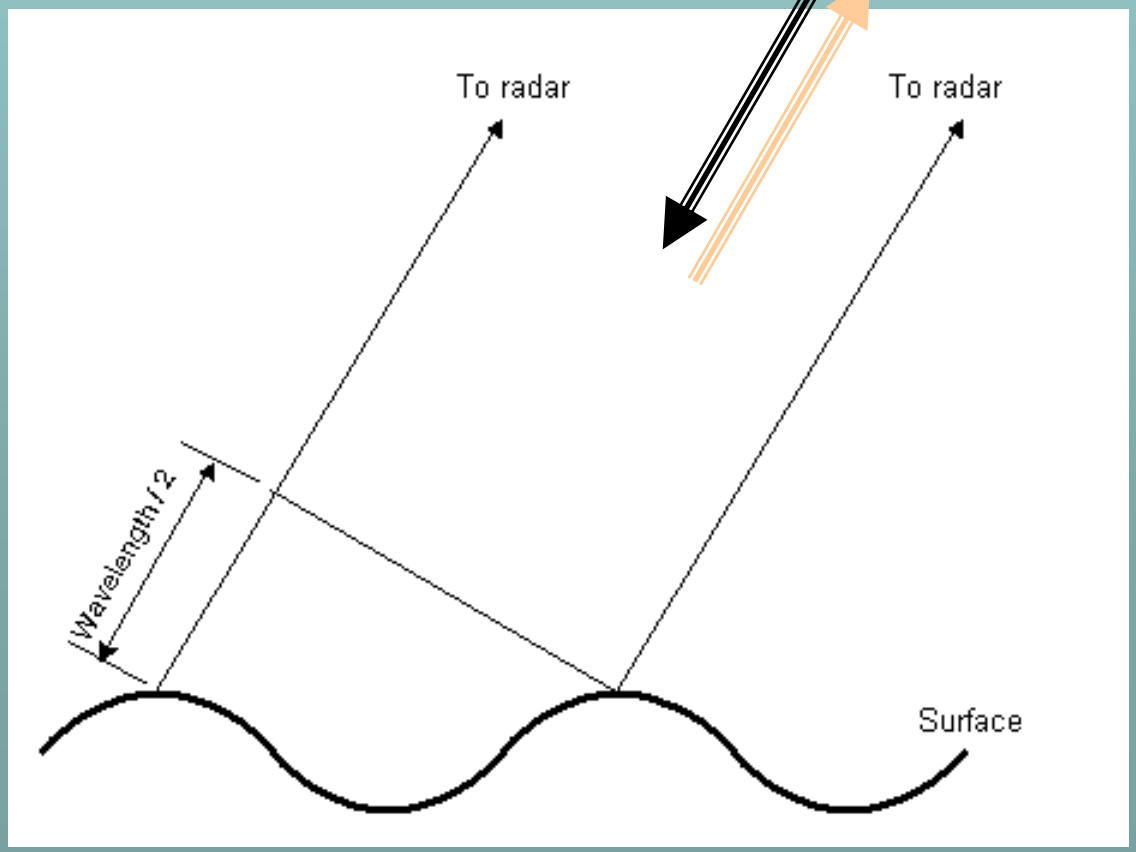
- Offshore winds from satellites
- Wind ressource estimation
- Wake estimation
- Conclusion

Motivation

Satellite data are complementary to: in-situ data…….that are costly

model results…….that are not fully verified

$$NormalizedRadarCrossSection = f(windspeed, winddirection)$$



Physics

Ocean surface roughens by wind interaction: Capillary and short gravity waves are generated.

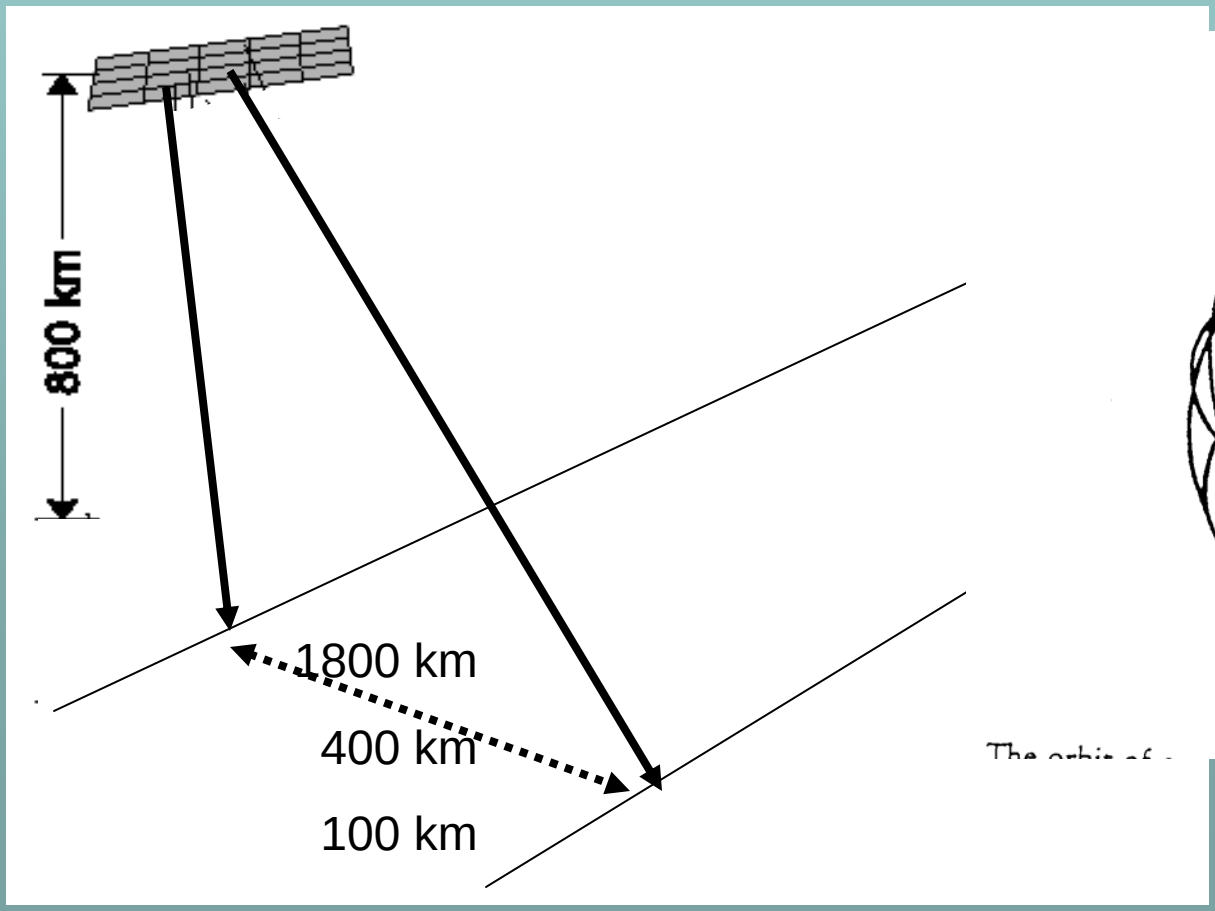
More wind causes more steep waves causes higher backscatter.

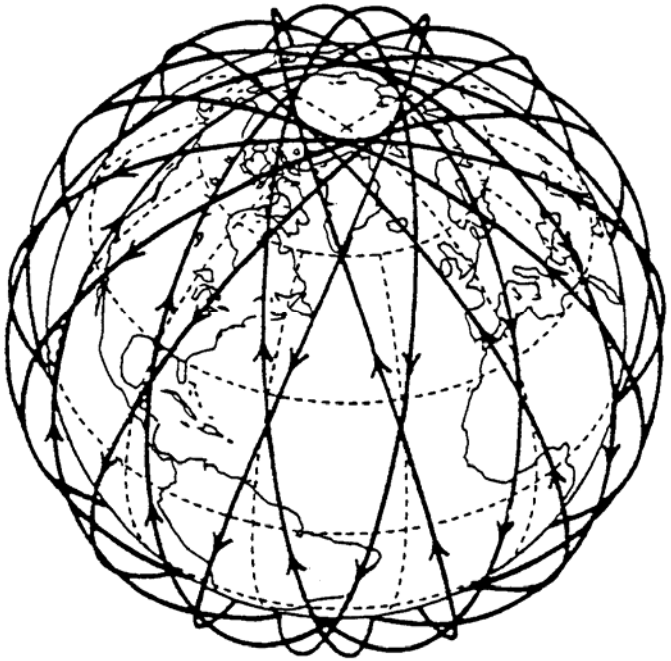
ERS

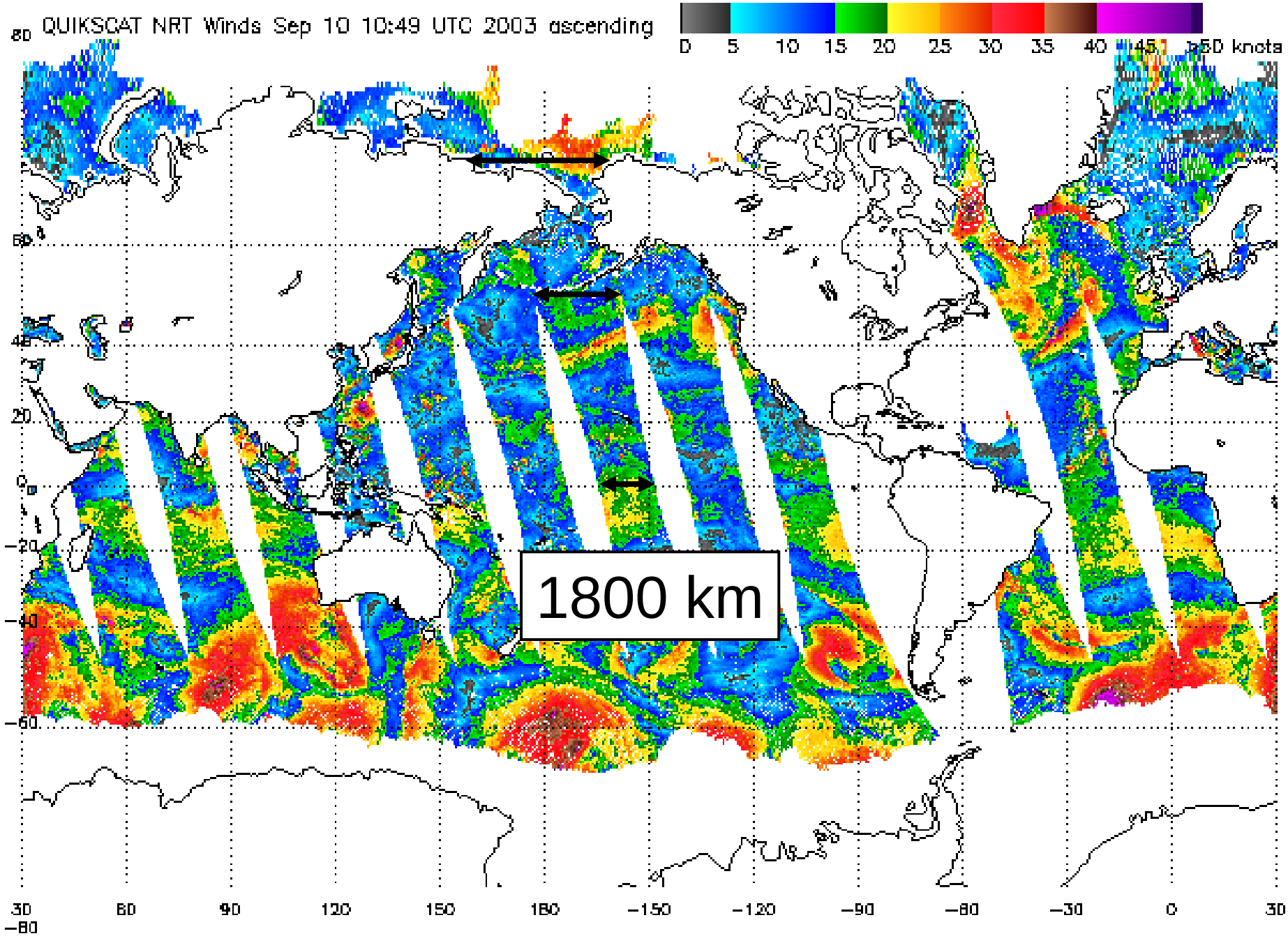
Envisat

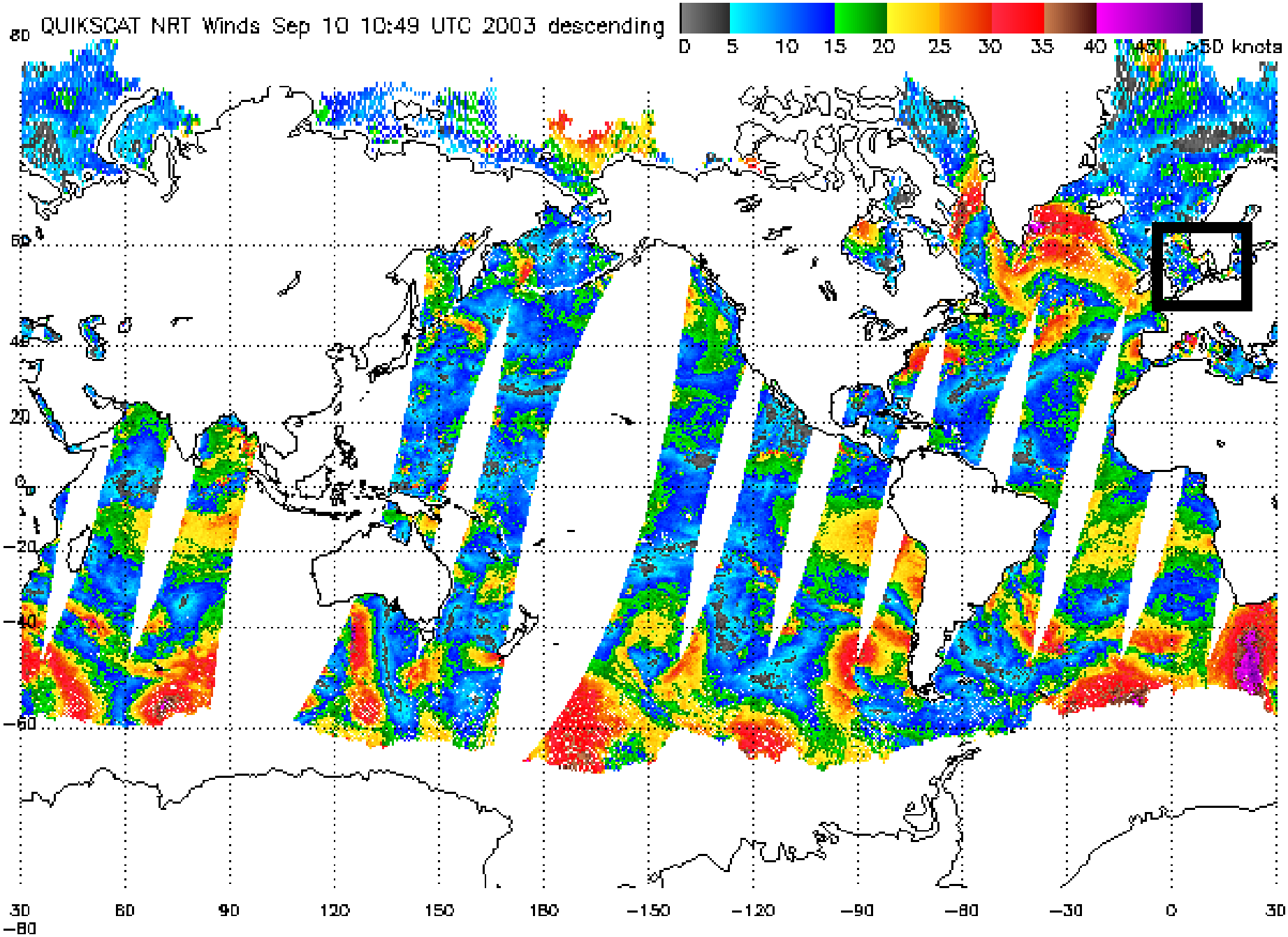
QuikScat

RISØ






QUIKSCAT NRT Winds Sep 10 10:49 UTC 2003 ascending
0 5 10 15 20 25 30 35 40 45 >50 knots
1800 km
80
60
40
20
0
−20
−40
−60
30 60 90 120 150 180 −150 −120 −90 −60 −30 0 30
−80


QUIKSCAT NRT Winds Sep 10 10:49 UTC 2003 descending
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80
60
40
20
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−20
−40
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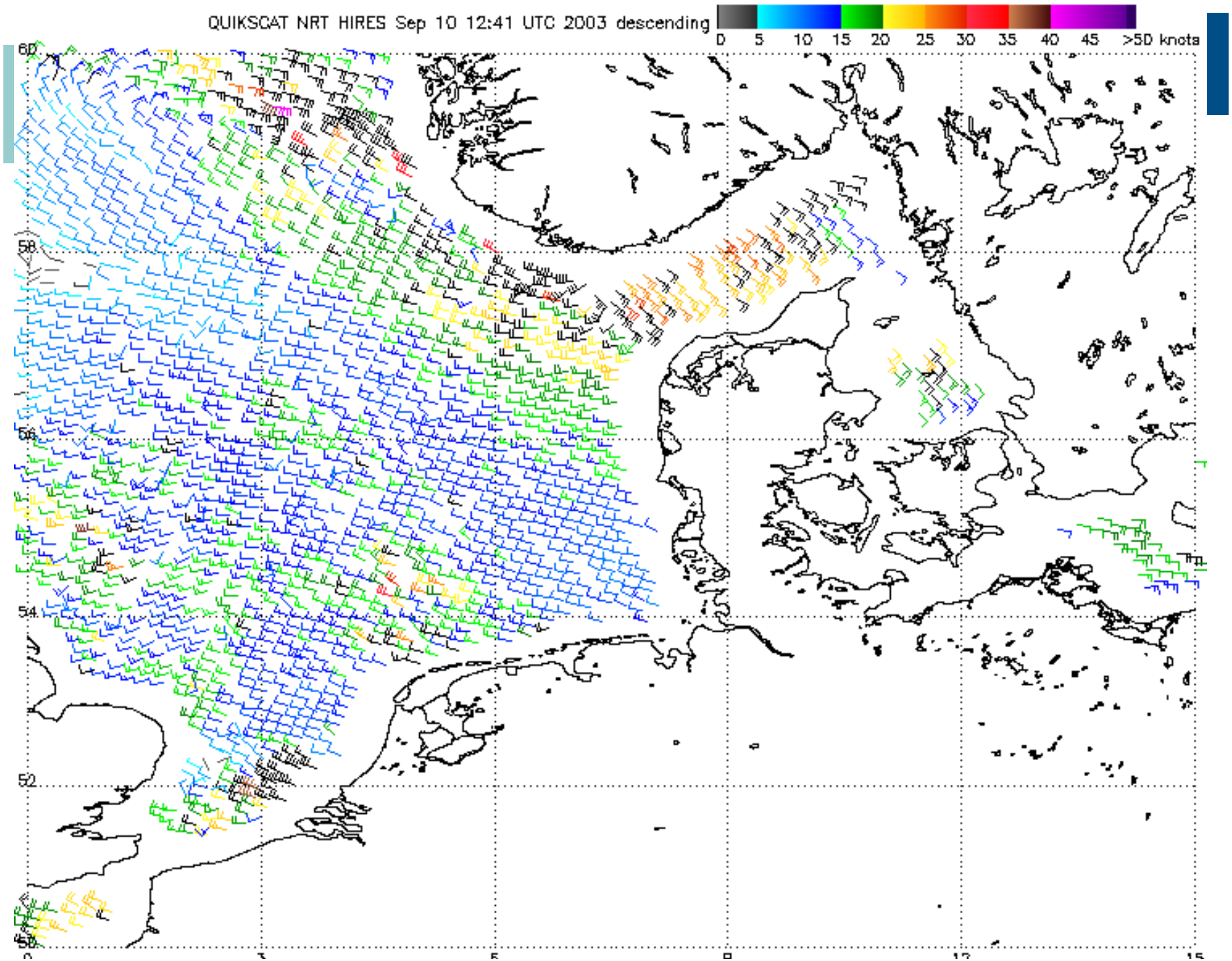
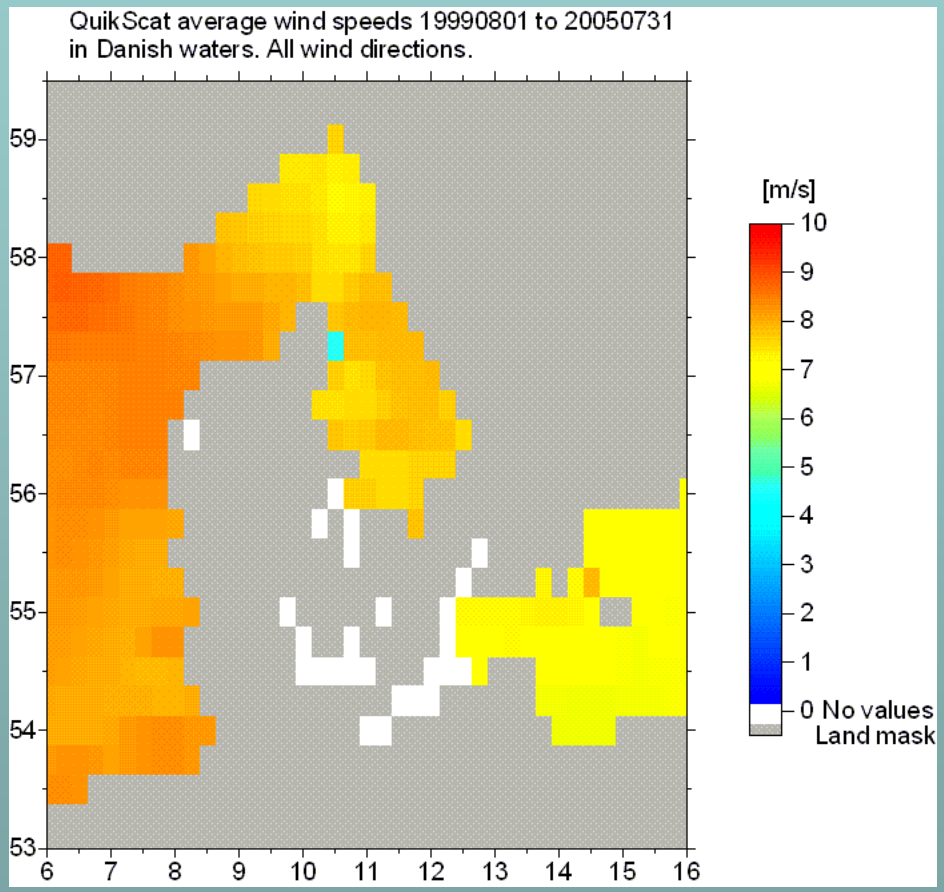
−80
30 60 90 120 150 180 −150 −120 −90 −60 −30 0 30


QUIKSCAT NRT HIRES Sep 10 12:41 UTC 2003 descending
0 5 10 15 20 25 30 35 40 45 >50 knots
60
58
56
54
52
50

QuikScat results: mean wind speed 5 years

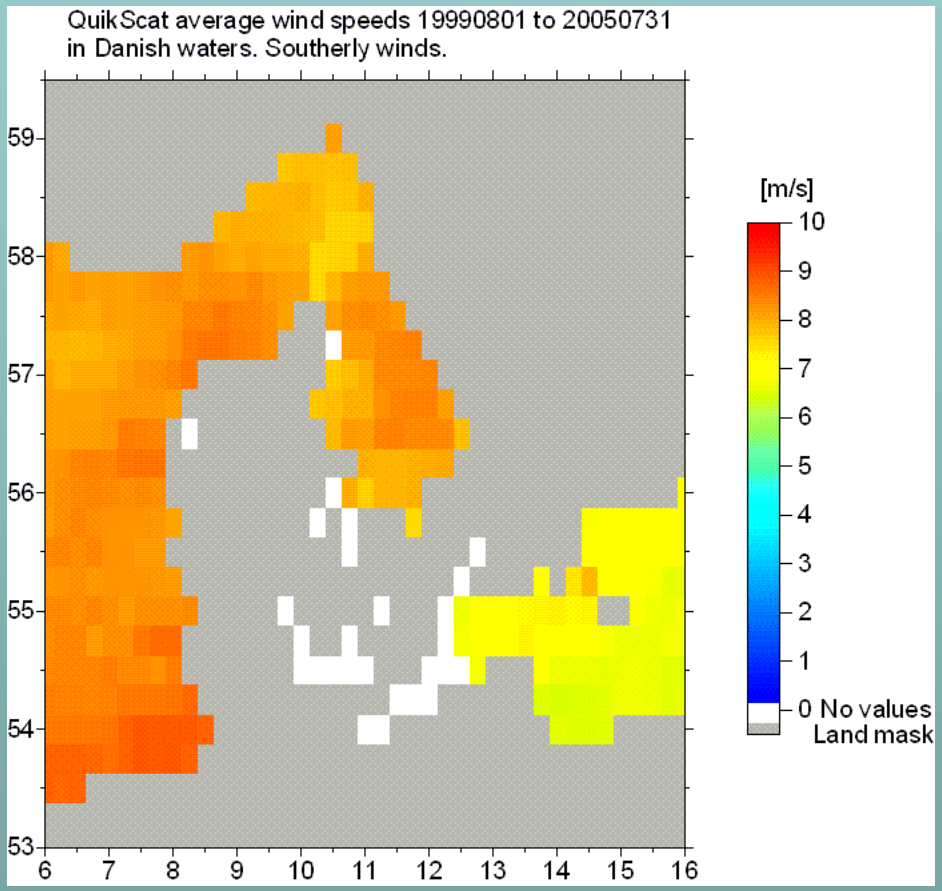


Grid cell:

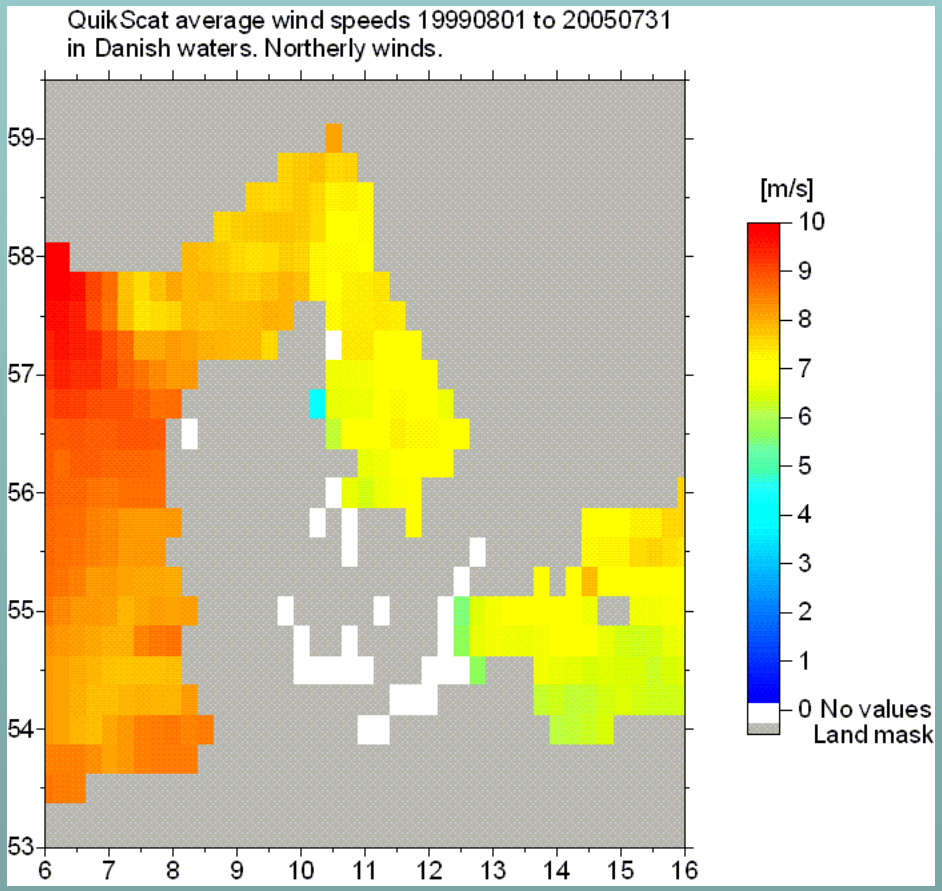
ca. 25 km

Number of observations: 3650 (twice per day for 5 years)

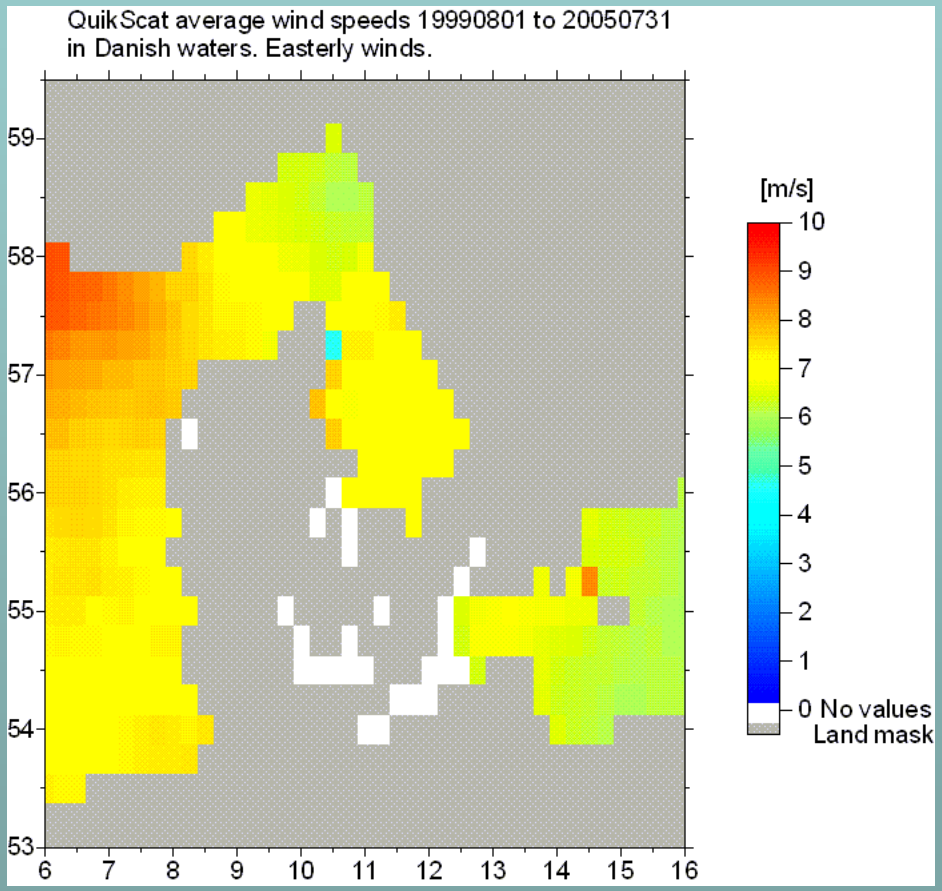
QuikScat results: mean wind speed south



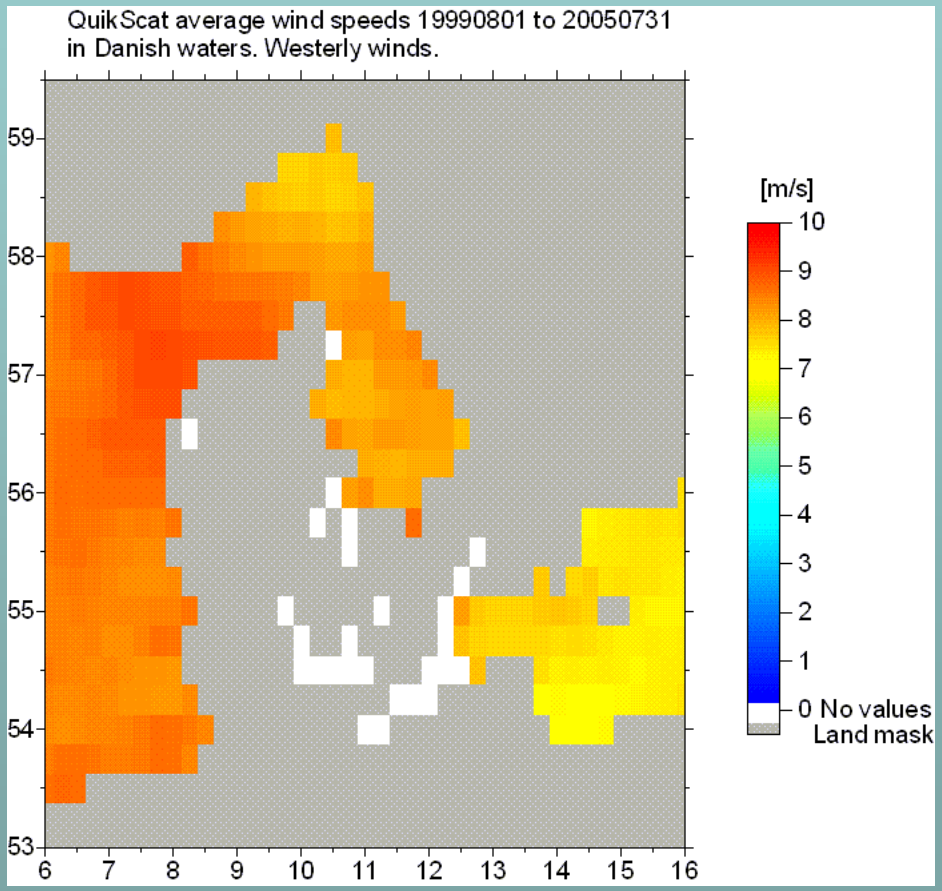
QuikScat results: mean wind speed north



QuikScat results: mean wind speed east



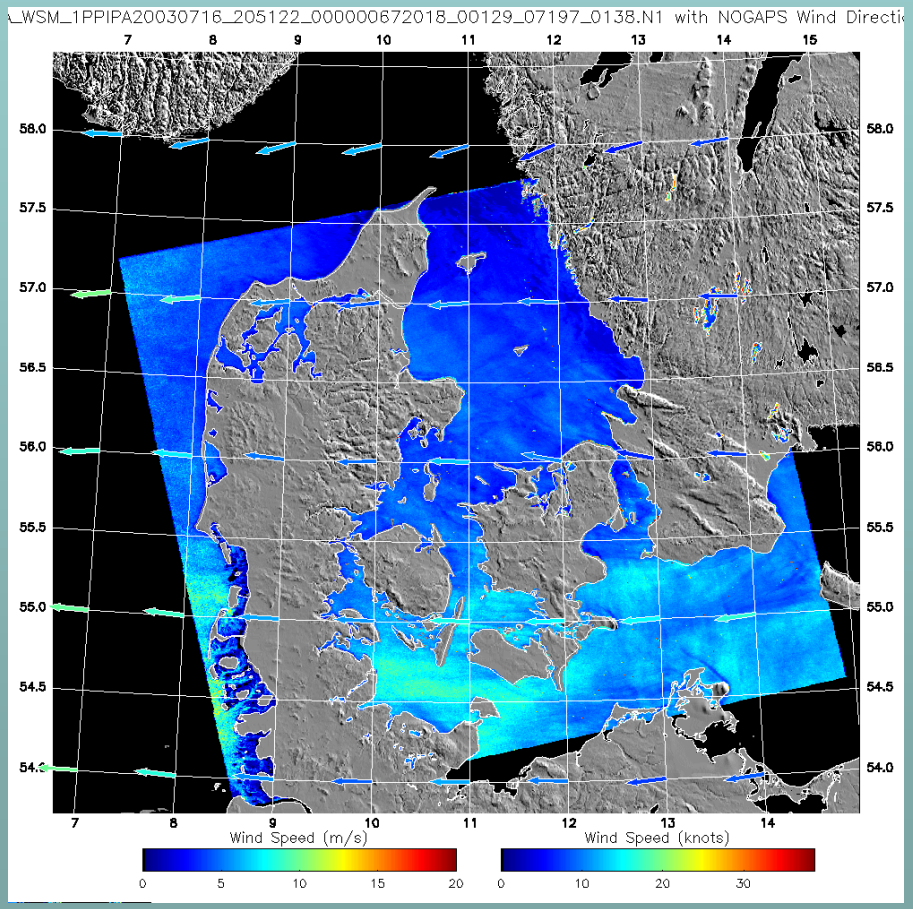
QuikScat results: mean wind speed west

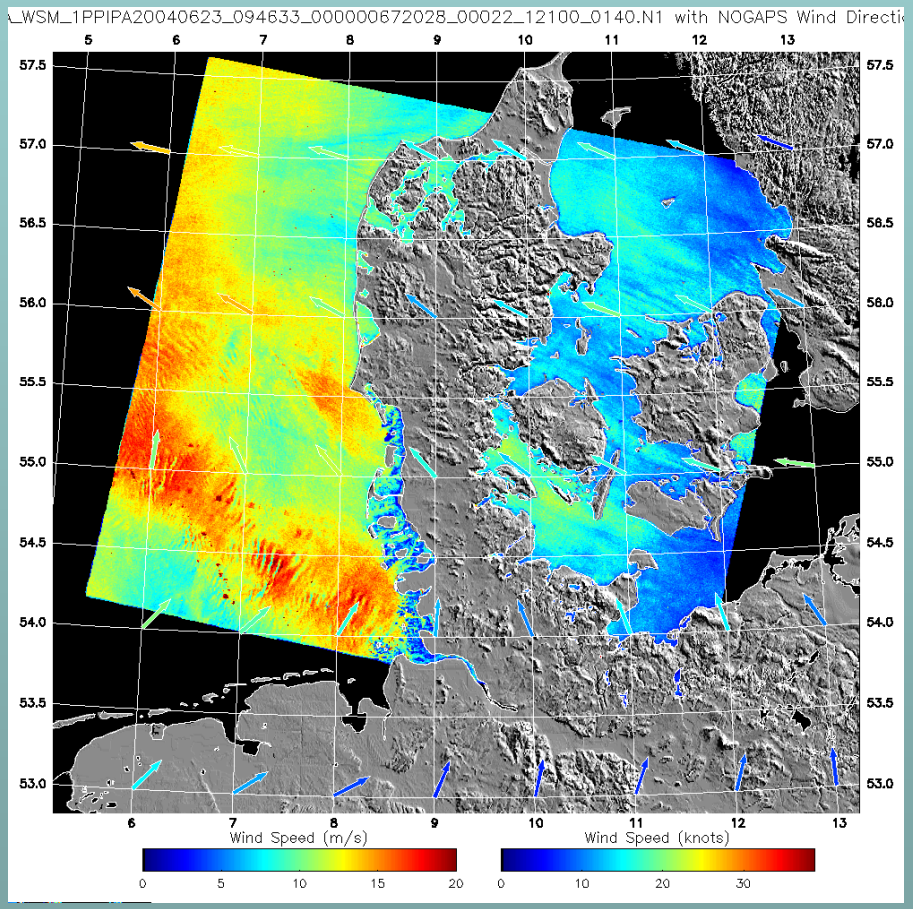


Also available: Weibull A and k per sector

in WASP tab-file format

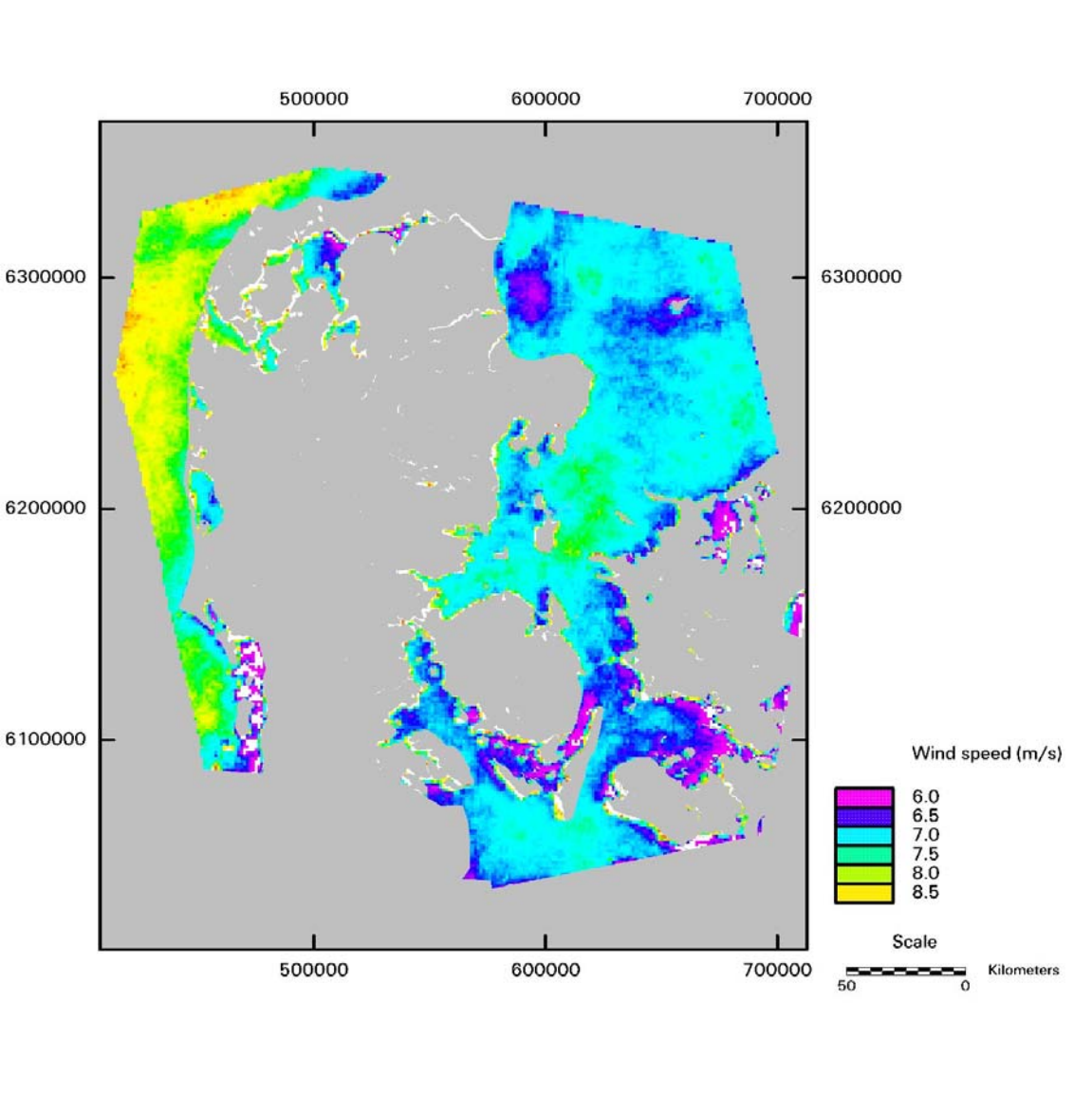
Envisat WSM: two snap-shots





Wind speed maps (Courtesy: JHU-APL)

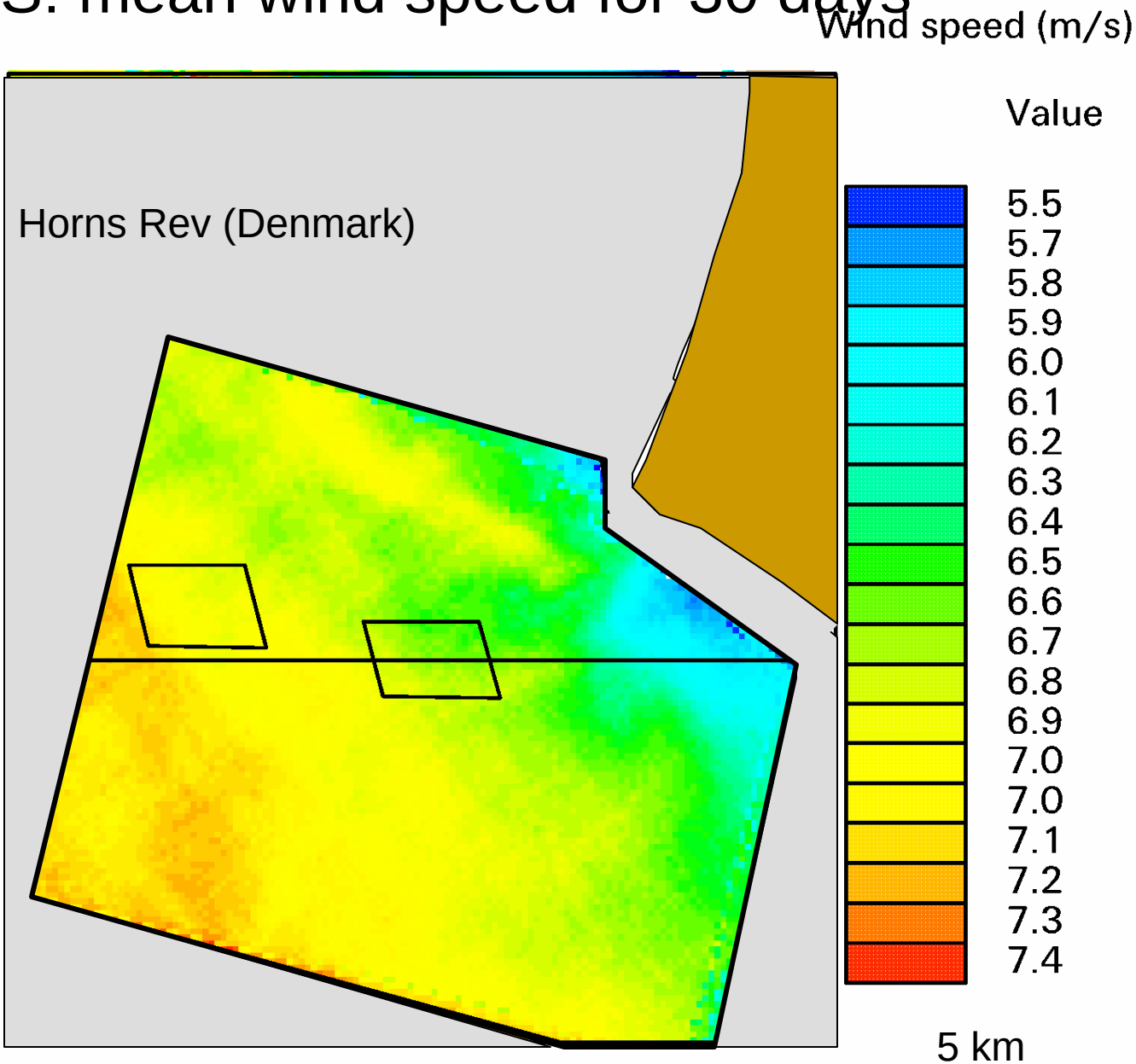
Envisat WSM: mean wind speed for 20 days



Grid cell:

1.6 km

ERS: mean wind speed for 30 days

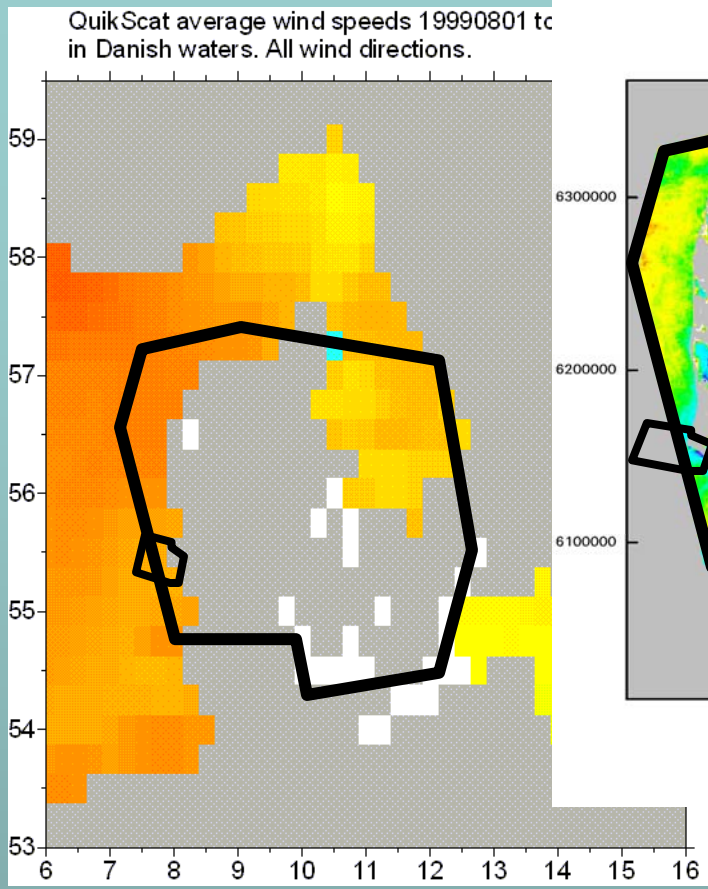


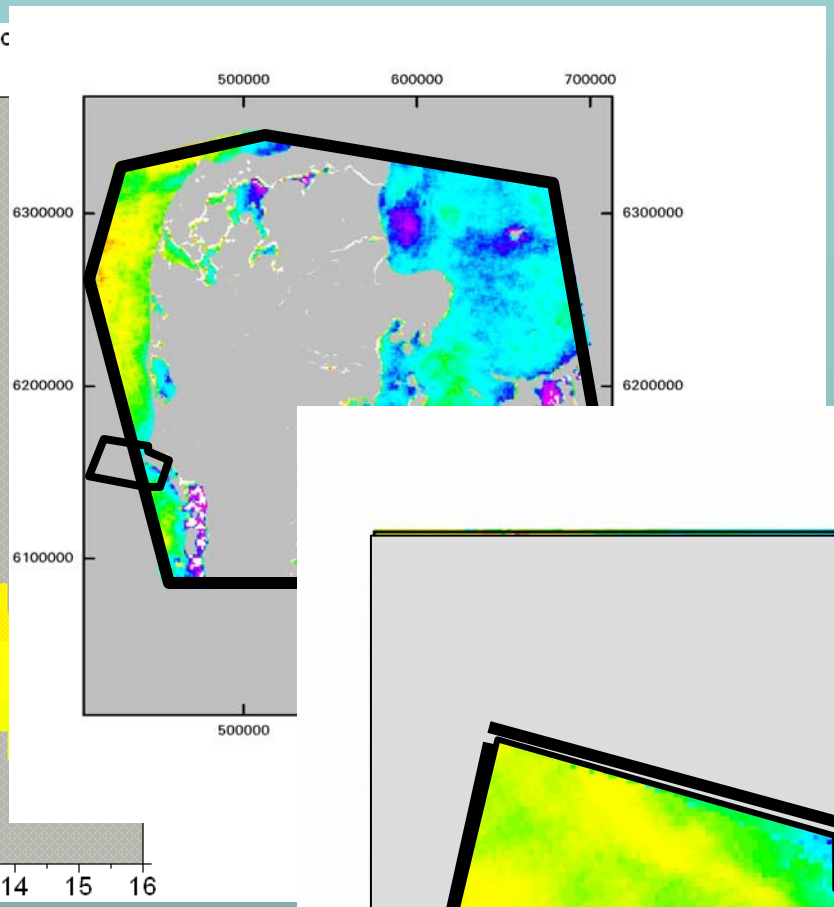
From Nielsen et al. 2004, Risø-R-1479(EN)

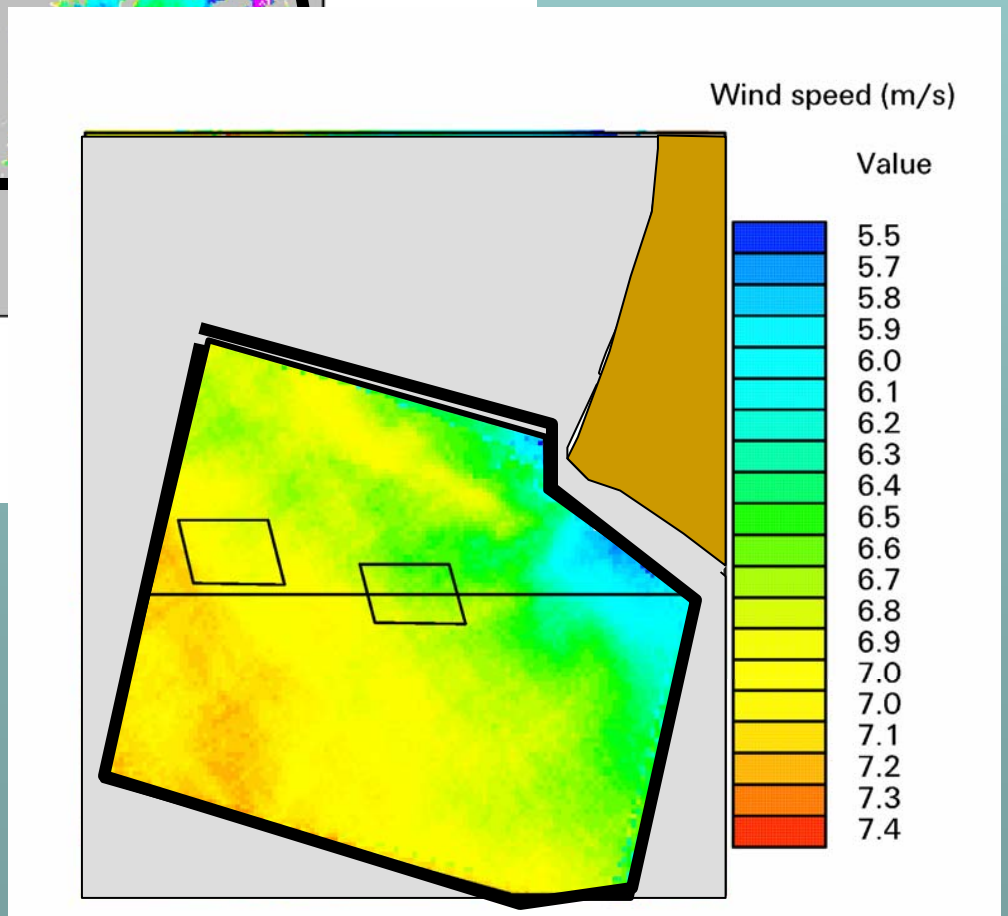
Grid cell:

400 m

Summary







QuikScat

25 km

Envisat WSM

1.6 km

ERS

400 m

Risø WEMSAR Tool version 2.0

Satelite images | Site statistics | Field statistics | Options

Selected scene

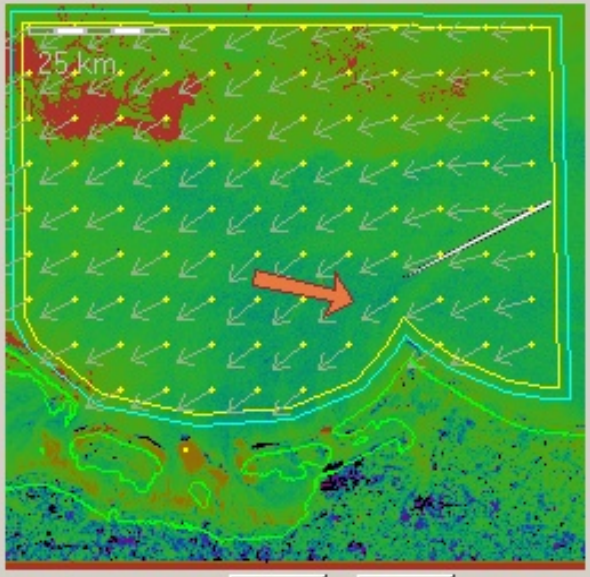
ORBIT: 23072
FRAME: 1107
CORNER COORDINATES:

(row,col) :	lat,lon	
(0,0) :	54.7957 ,	7.4037
(256,0) :	55.6865 ,	7.0055
(256,250) :	55.8960 ,	8.5567
(0,250) :	55.0024 ,	8.9191

PIXEL SIZE: 400m x 400m
UTM 32

(row,col) :	East	North
(0,0) :	397368	6073358
(256,0) :	374605	6173127
(256,250) :	472277	6194730
(0,250) :	494825	6095194

Field



Copy | Save

Selected site

Latitude 55.5077
Longitude 7.87499

Coordinates
- Geographi
- UTM

Turbine hub height (m) 65

Show stream ☑
Show boundar ☑
Show footprint ☑
Show coast ☑
Show north ☑
Show scale ☑

Displayed field
- none
- wind speec
- wind directi
- filtered spe

Footprint contour (%) 5

List of satelite scenes

☑ 21340_1107_990!	☑ 23509_2493_991
☑ 21777_2482_990	☑ 24010_2493_991
☑ 21798_1107_990	☑ 24160_1107_991
☑ 22006_2486_990	☑ 24346_1107_991
☑ 22070_1107_990	☑ 24783_2493_000
☑ 22342_1107_990	☑ 25012_2493_000
☑ 22507_2493_990	☑ 25348_1107_000
☑ 22800_1107_990	☑ 25513_2493_000
☑ 23072_1107_990	☑ 25785_2475_000
☑ 23280_2493_991	☑ 26014_2486_000
☑ 23344_1107_991	☑ 26078_1107_000

All | None | Store | Load

Boundary

454105	6138391
446958	6148916
440092	6152794
434432	6154851
436474	6158256
439239	6165602
441001	6175655
440720	6182302
440187	6184696
380013	6169212
399791	6076850

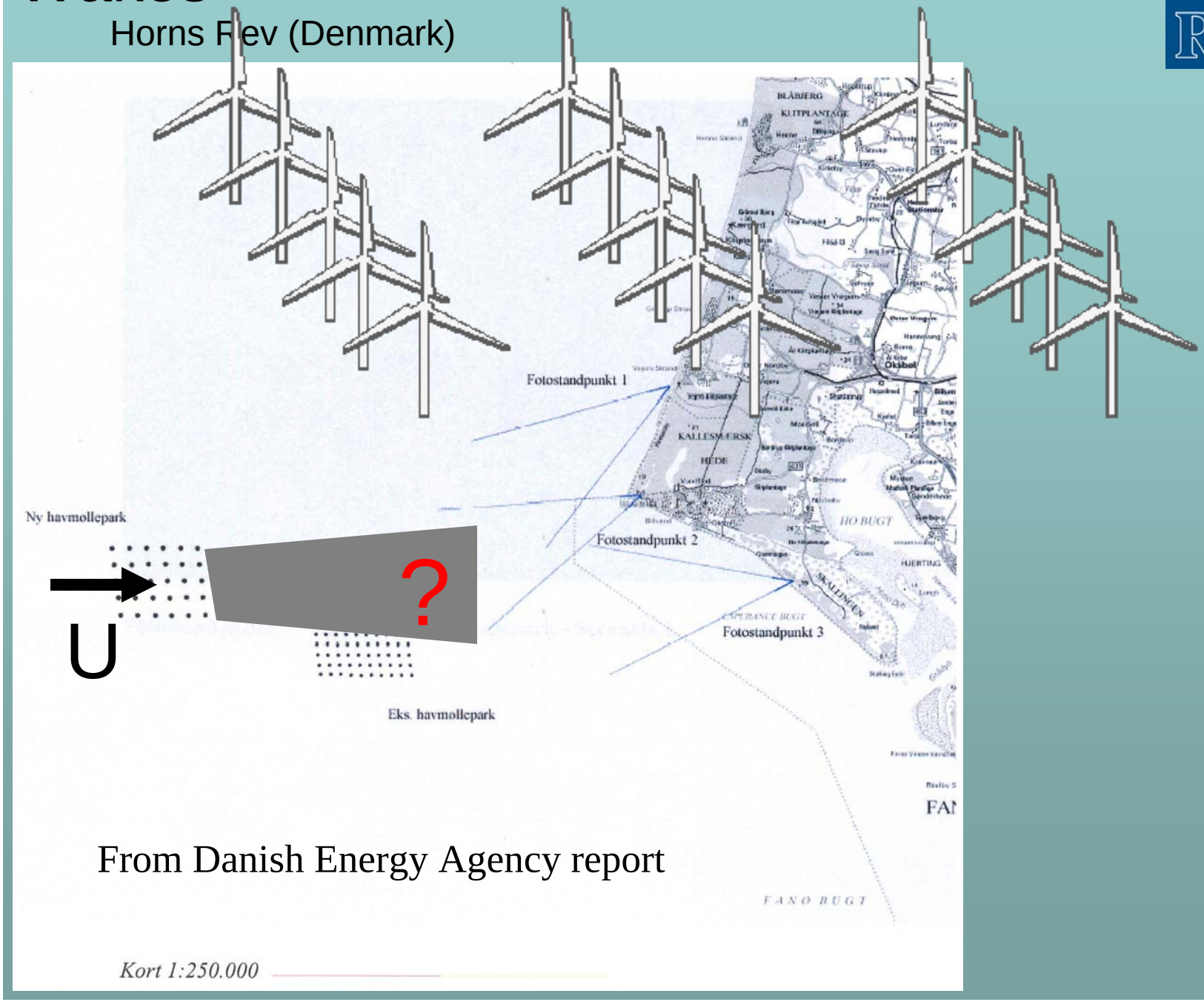
Max Boundar | Save Boundary

List of scenes using all data within boundary

☐ 21340_1107_9905	☐ 23509_2493_991
☐ 21777_2482_9906	☐ 24010_2493_991
☐ 21798_1107_9906	☐ 24160_1107_991
☐ 22006_2486_9907	☐ 24346_1107_991
☐ 22070_1107_9907	☐ 24783_2493_000
☐ 22342_1107_9907	☐ 25012_2493_000
☐ 22507_2493_9908	☐ 25348_1107_000
☐ 22800_1107_9908	☐ 25513_2493_000
☐ 23072_1107_9909	☐ 25785_2475_000
☐ 23280_2493_9910	☐ 26014_2486_000
☐ 23344_1107_9910	☐ 26078_1107_000

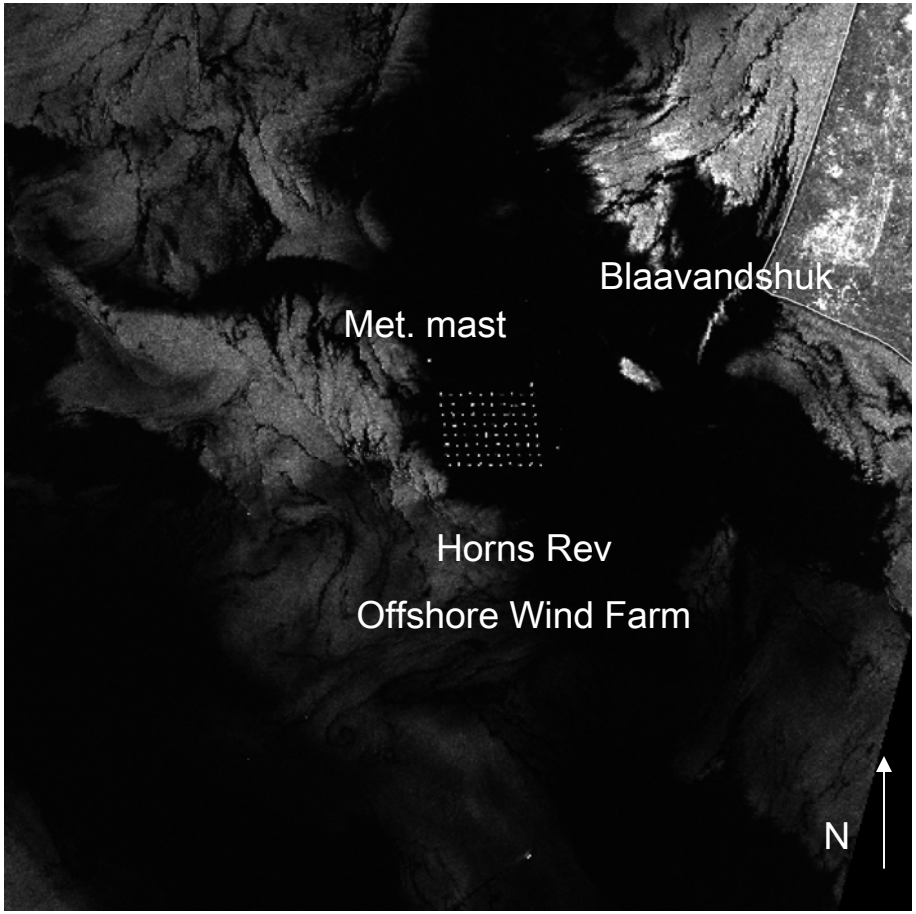
Wakes

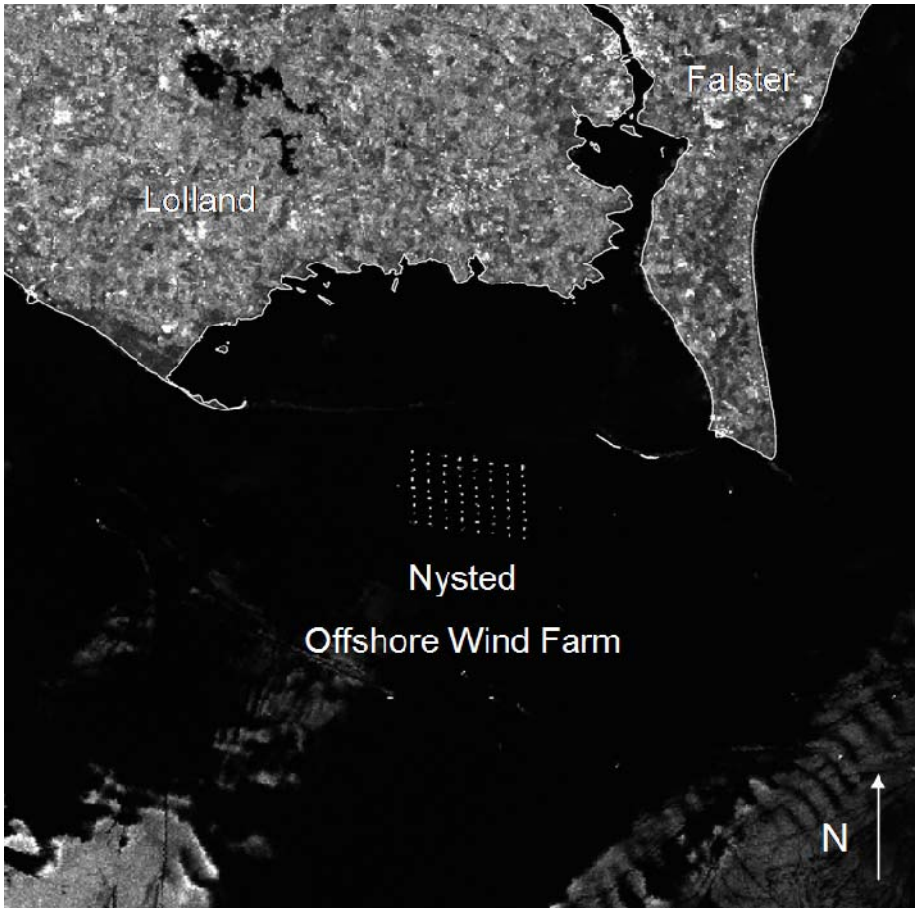
Horns Rev (Denmark)



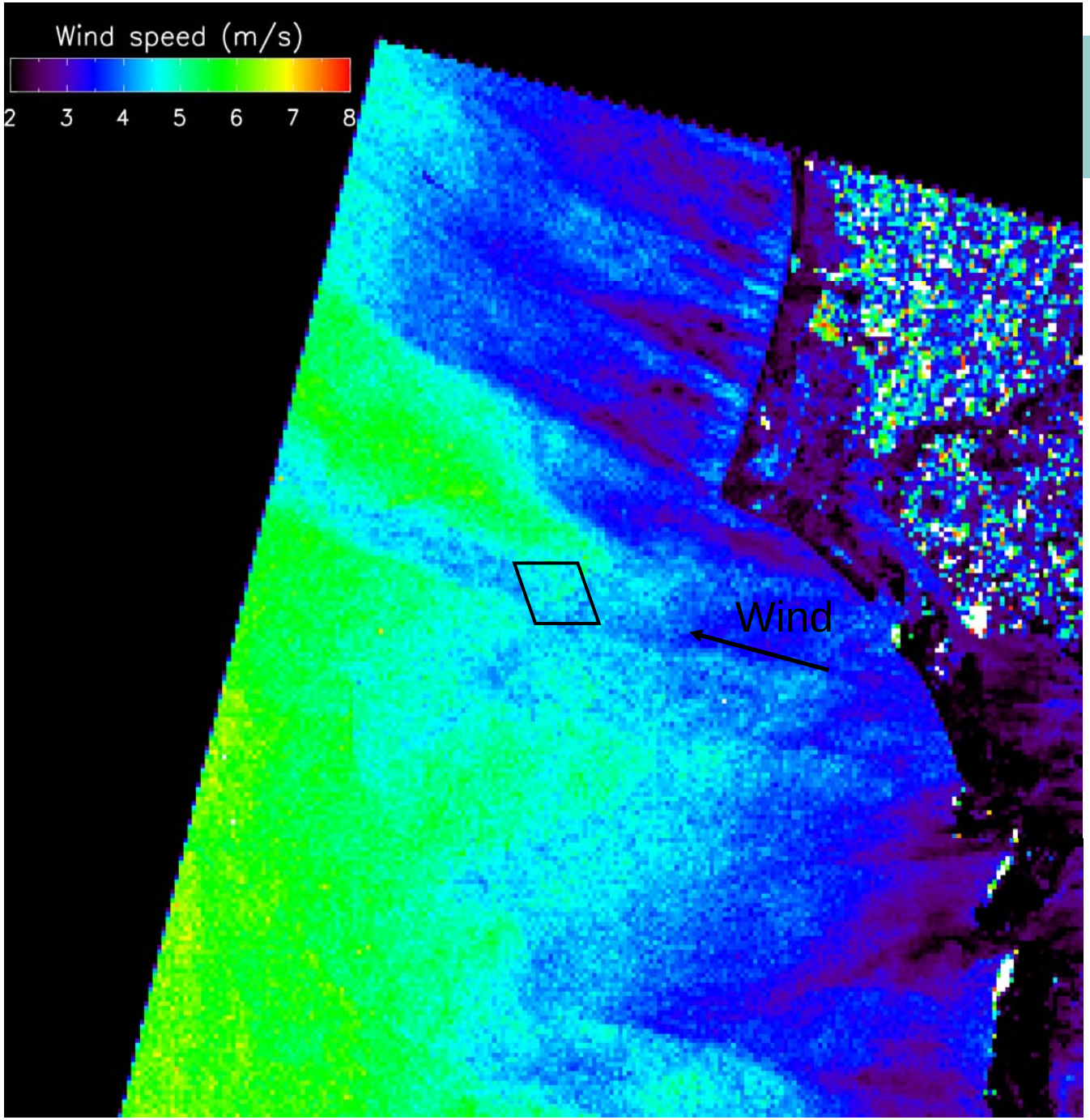
From Danish Energy Agency report

Study sites: Horns Rev and Nysted



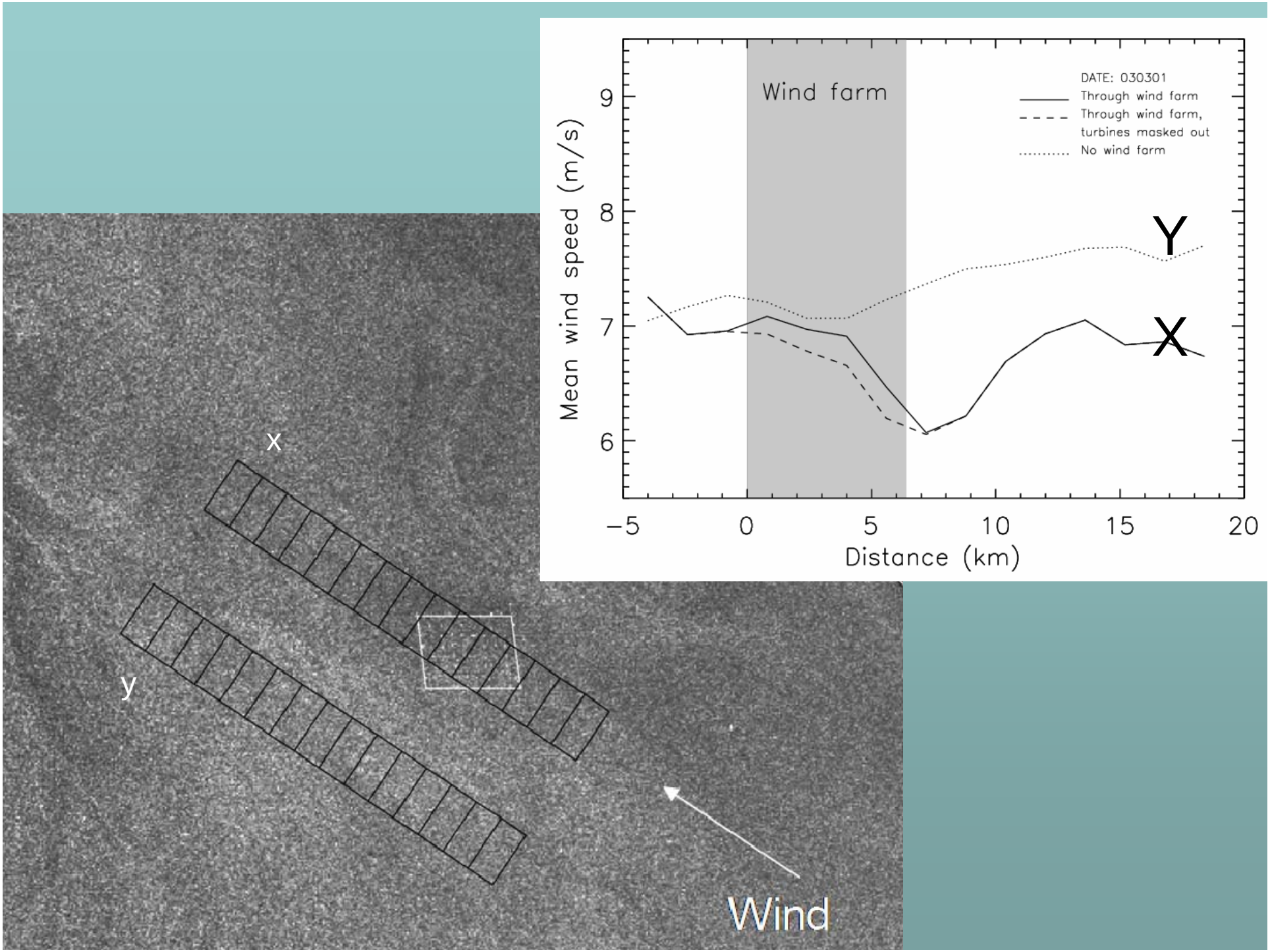


ERS-2 raw images (no wind)



Horns Rev

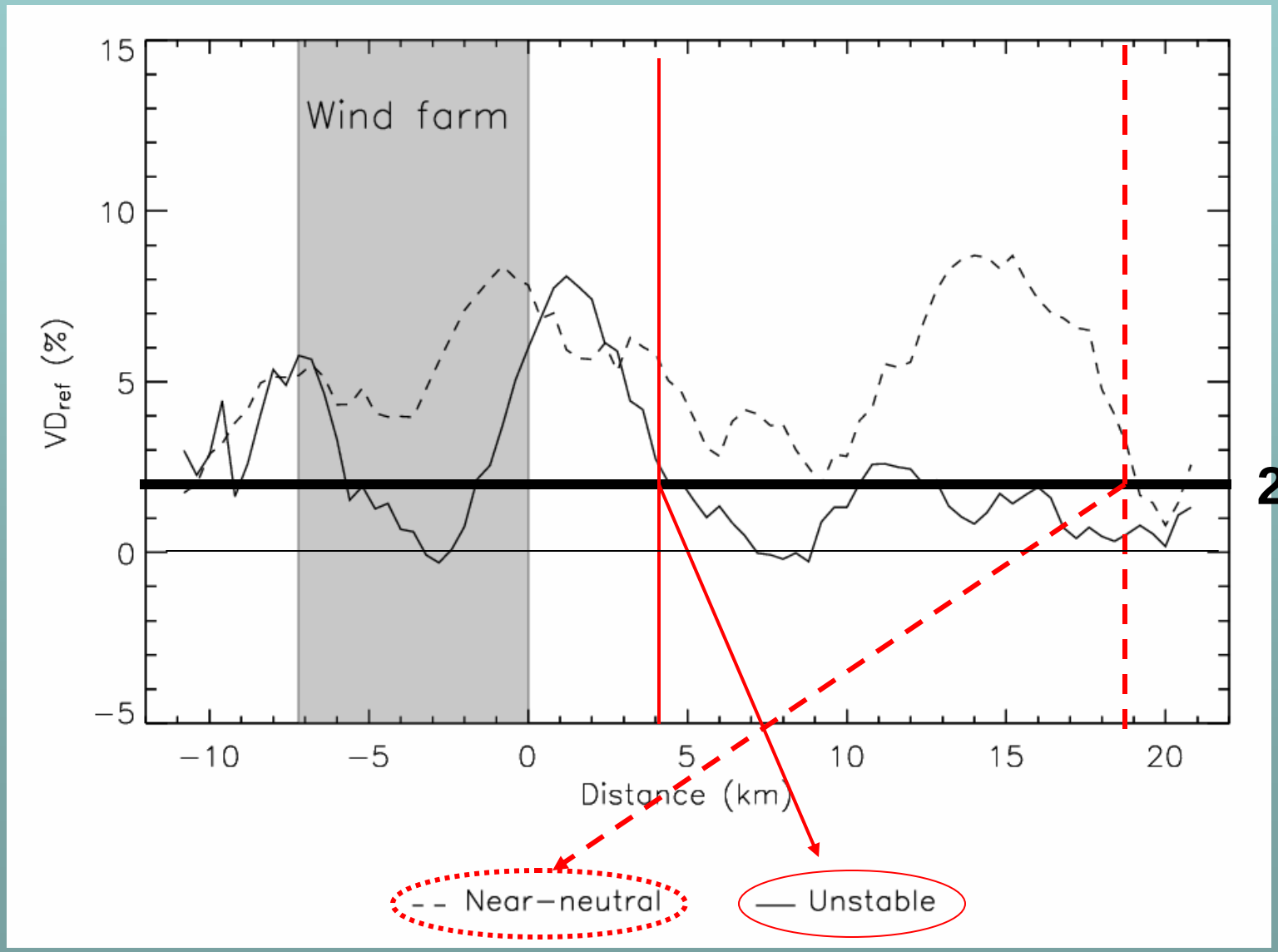
Wind speed map from ERS


Wind farm
DATE: 030301
Through wind farm
Through wind farm, turbines masked out
No wind farm
Mean wind speed (m/s)
Distance (km)
Y
X
x
y
Wind

Velocity deficit (VD):

$$VD = \frac{U(y) - U(x)}{U(y)} 100\%$$

Velocity deficit vs. atmospheric stability



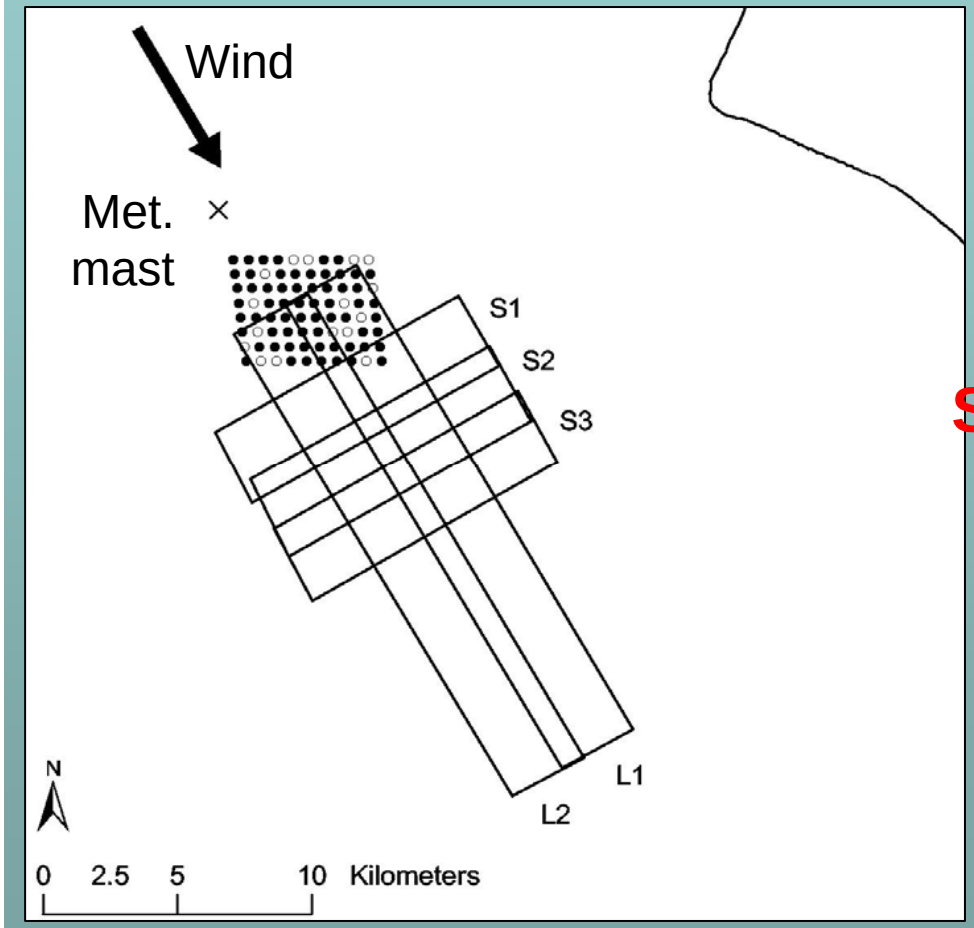
Wind maps from airborne SAR using the ESAR (DLR)

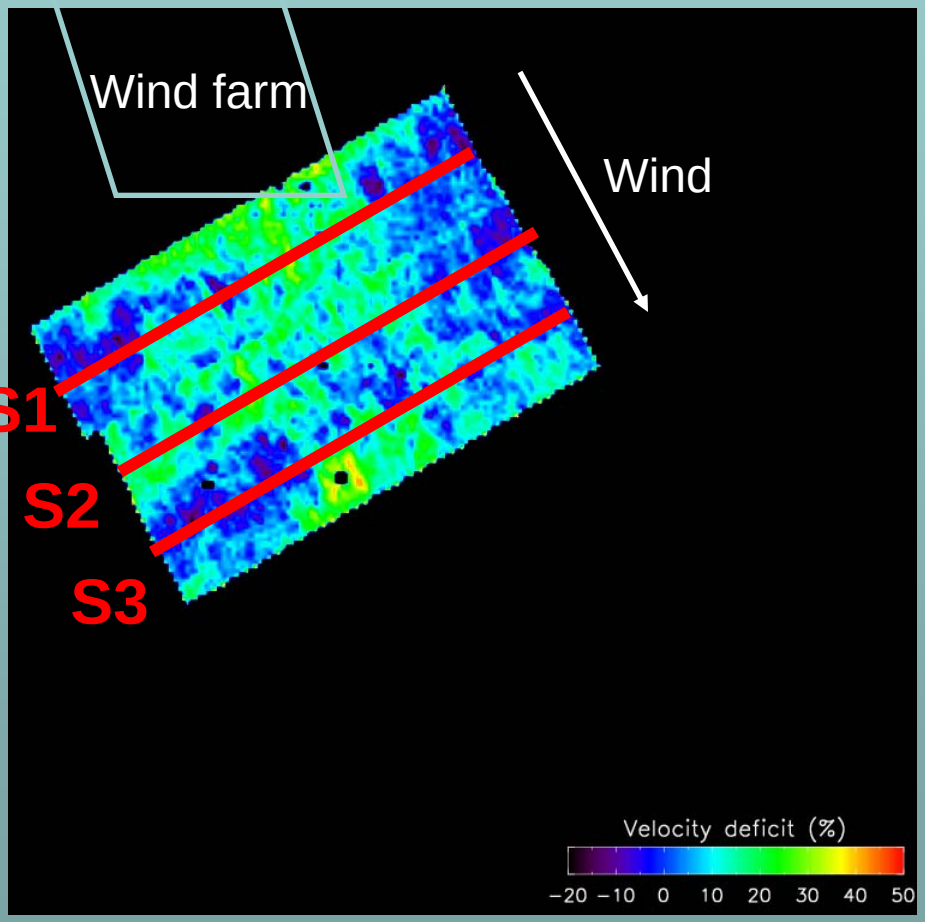
Bands and polarizations: C_{VV}, C_{HH}, L_{VV} and L_{HH}

E-SAR at Dornier in Esbjerg (Denmark), 12 October 2003

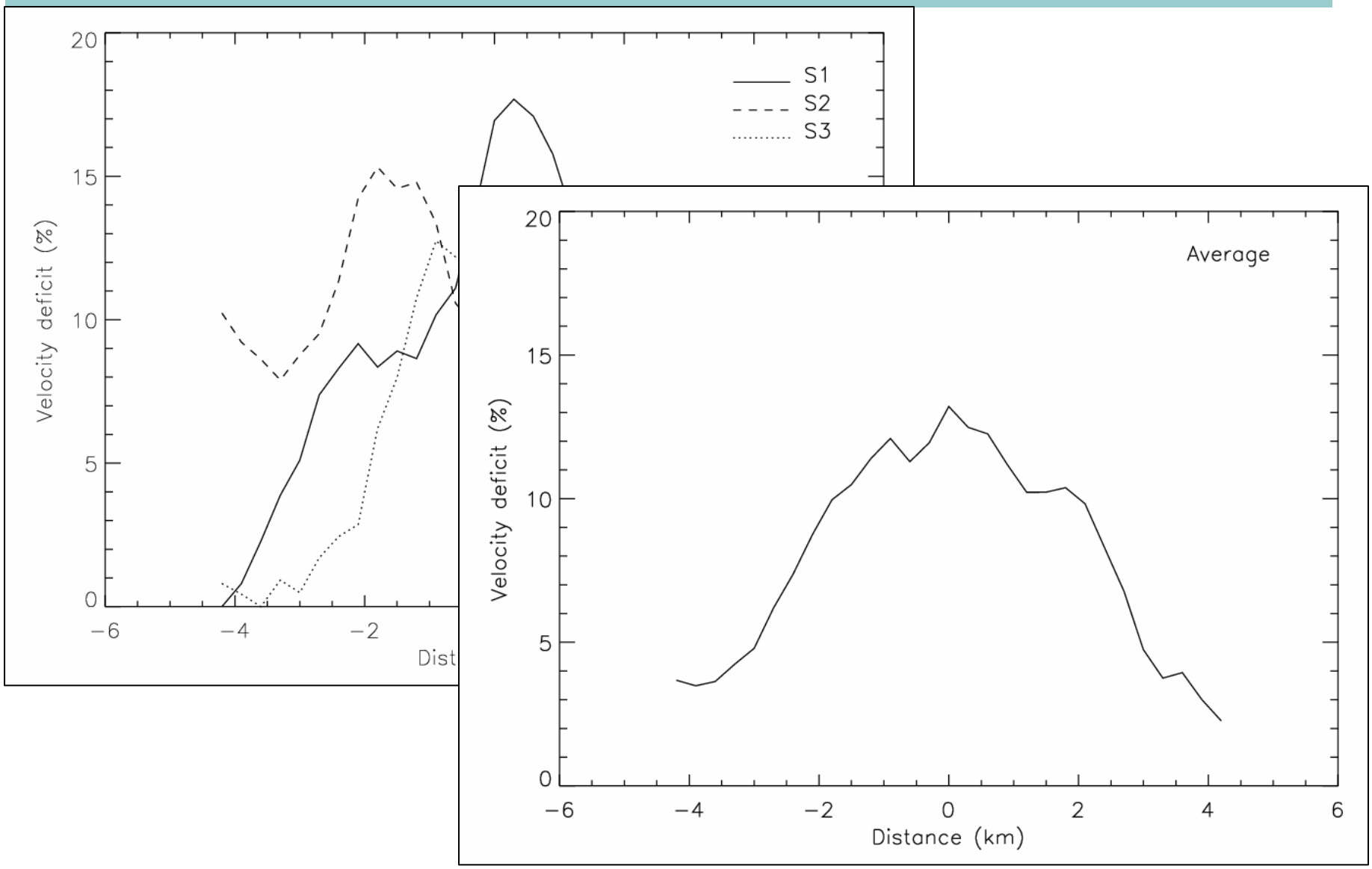
E-SAR flight tracks

Velocity deficit (%)





Velocity deficit, cross wind tracks



Conclusions

- Satellite ocean wind from many satellites are used to calculate:

mean wind speed, Weibull A and k per wind sector for the Danish seas.

- Results are in WASP tab-file format

- Software for users is in development

- Wake near large offshore wind farms is quantified in space and time

Acknowledgements

Danish Research Agency: SAT-WIND and SAR-WAKE projects;

ESA: EO-windfarm and EO-1356 projects;

Elsam Engineering.