



Using satellite data for mapping offshore wind resources and wakes

Charlotte Bay Hasager, Merete Bruun Christiansen, Poul Astrup,
Morten Nielsen and Rebecca Barthelmie

Risø National Laboratory, Wind Energy Department, Denmark

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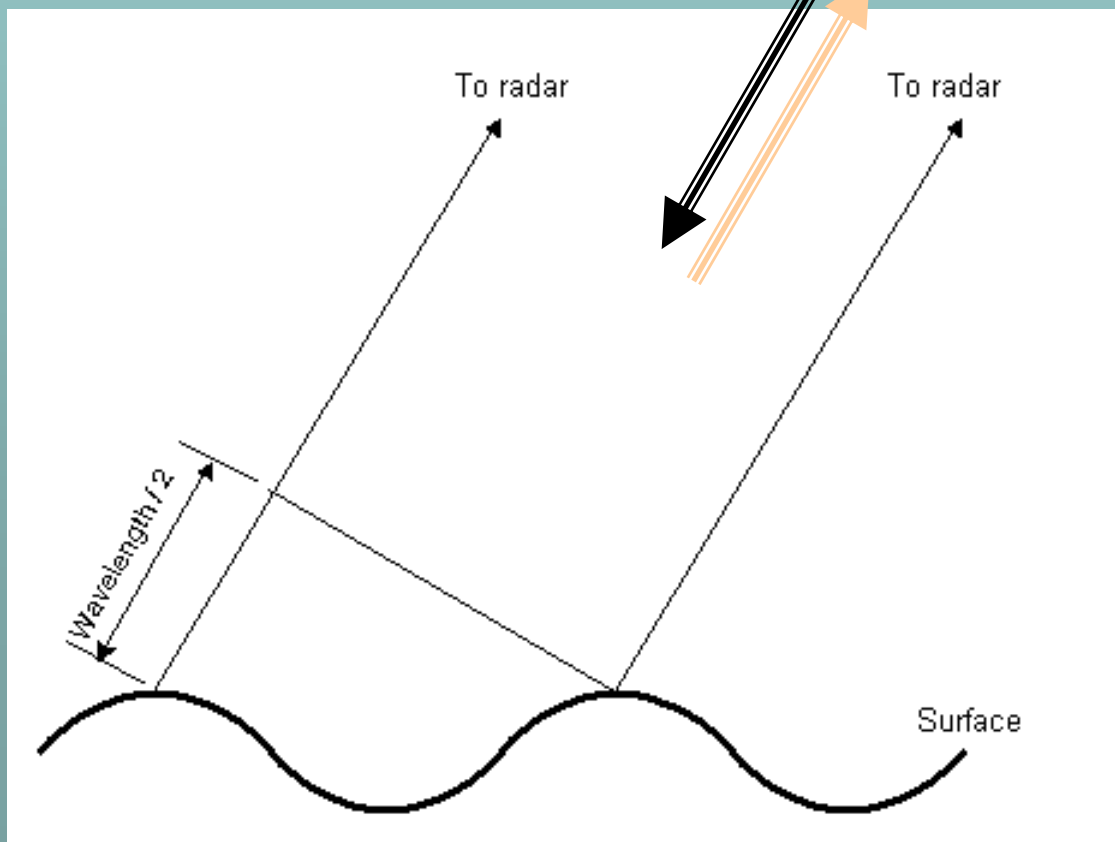
- Offshore winds from satellites
- Wind resource estimation
- Wake estimation
- Conclusion

Motivation

Satellite data are complementary to: in-situ data.....that are costly
model results.....that are not fully verified

Normalized Radar Cross Section = f(windspeed, winddirection)

RISØ



Physics

Ocean surface roughens by wind interaction:

Capillary and short gravity waves are generated.

More wind causes more steep waves causes higher backscatter.

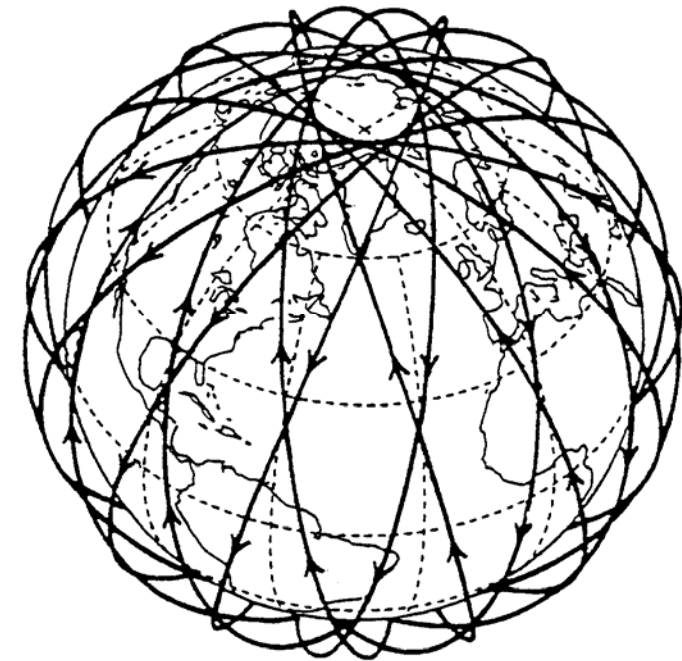
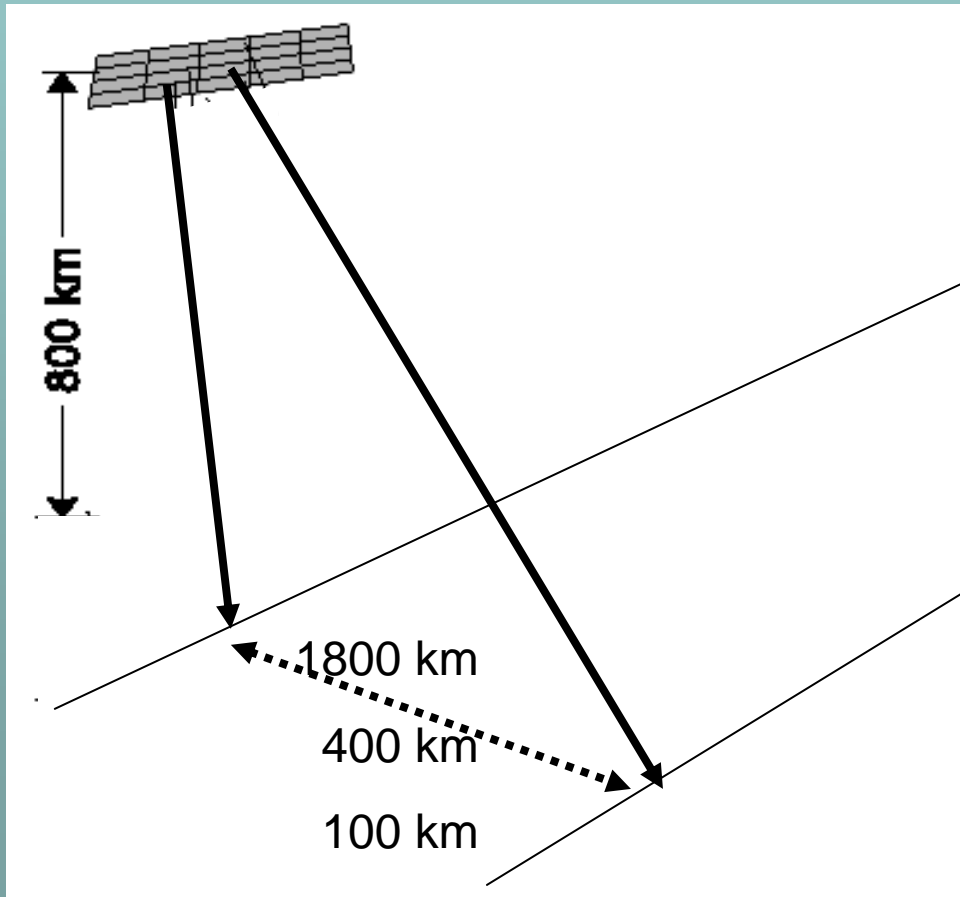
ERS



Envisat

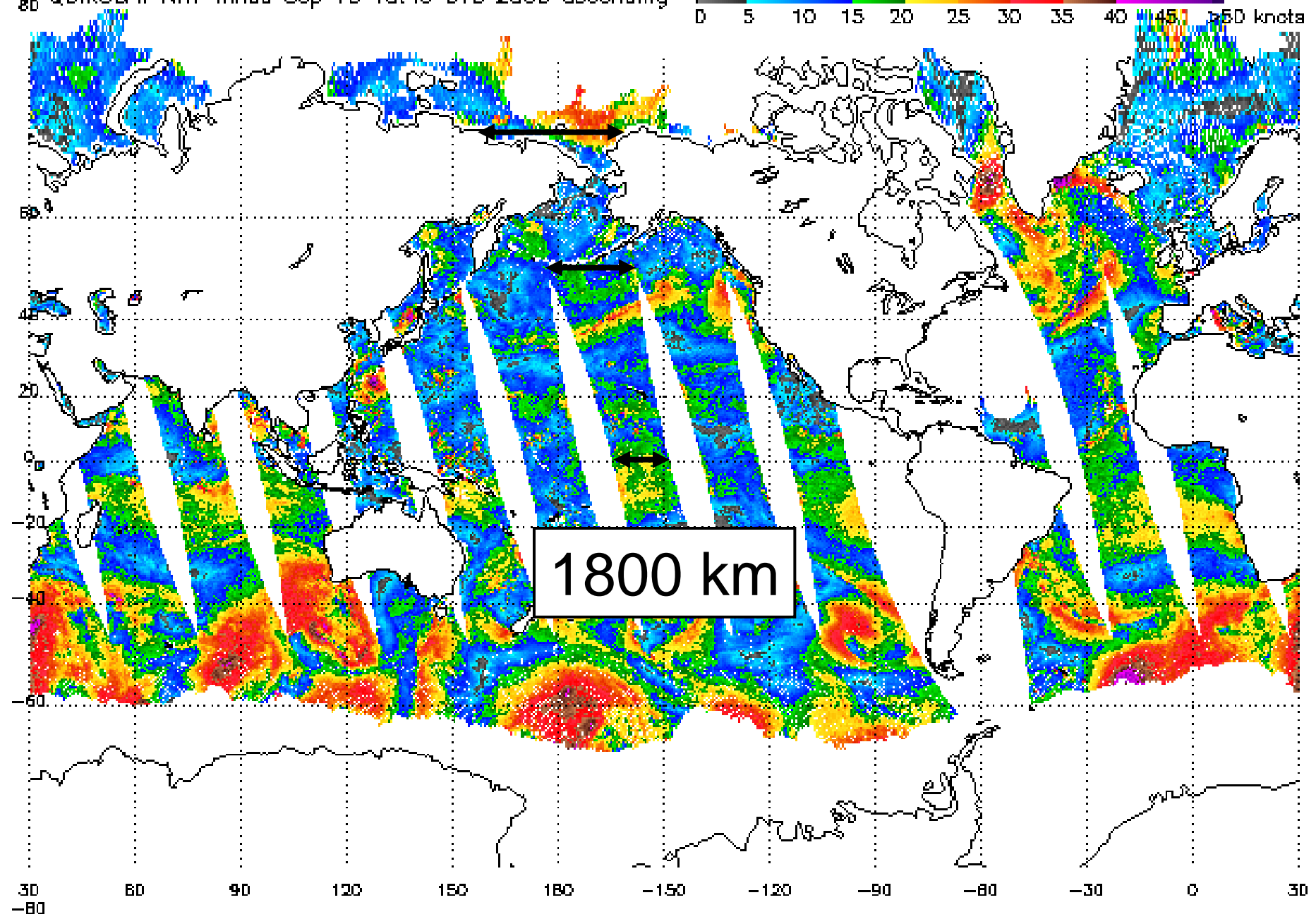
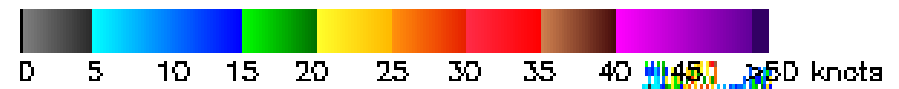


QuikScat

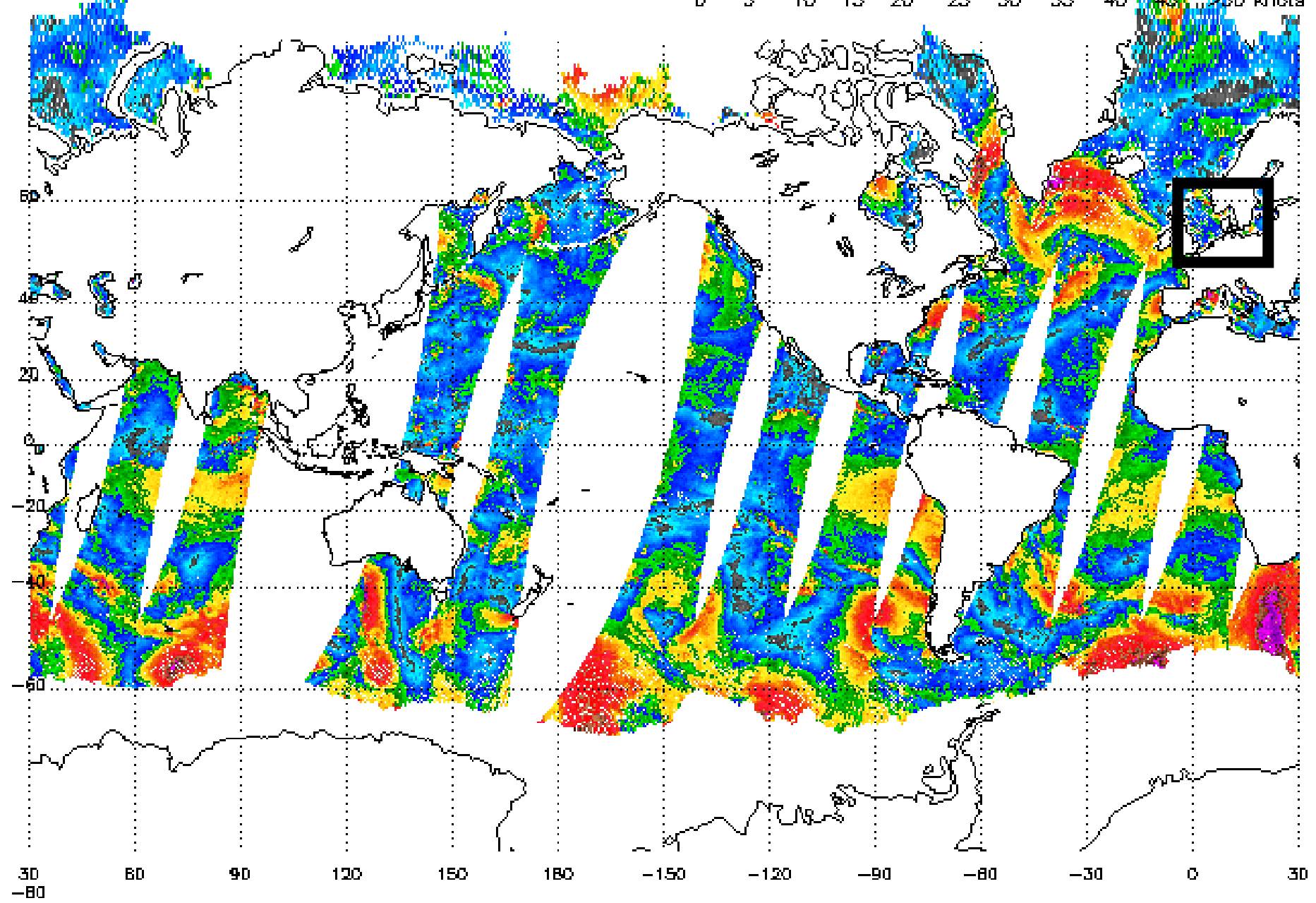
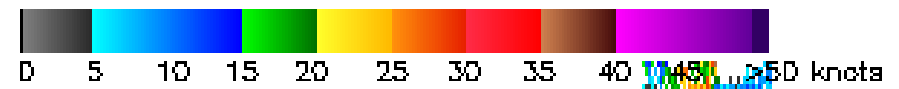


The orbit of -

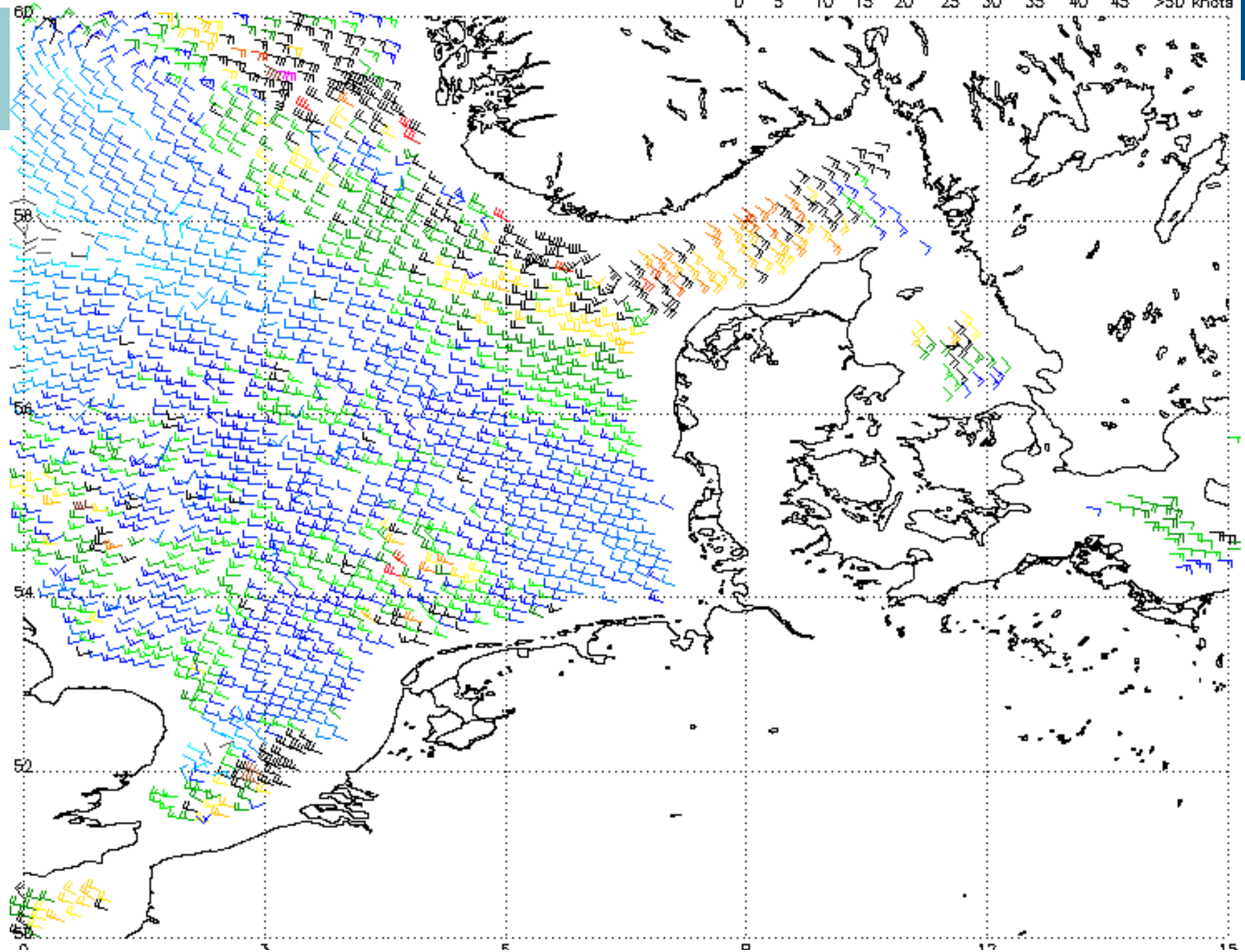
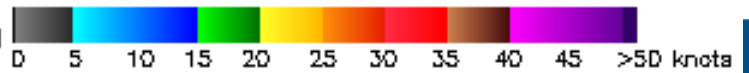
80 QUIKSCAT NRT Winds Sep 10 10:49 UTC 2003 ascending



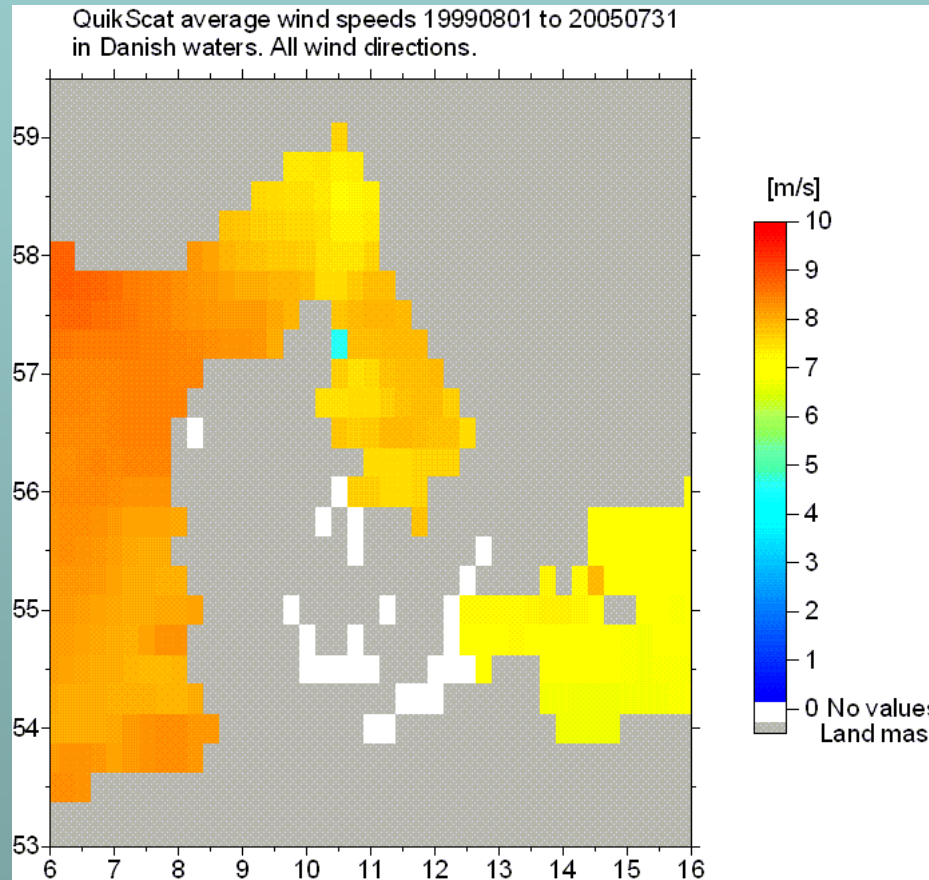
80 QUIKSCAT NRT Winds Sep 10 10:49 UTC 2003 descending



QUIKSCAT NRT HIRES Sep 10 12:41 UTC 2003 descending



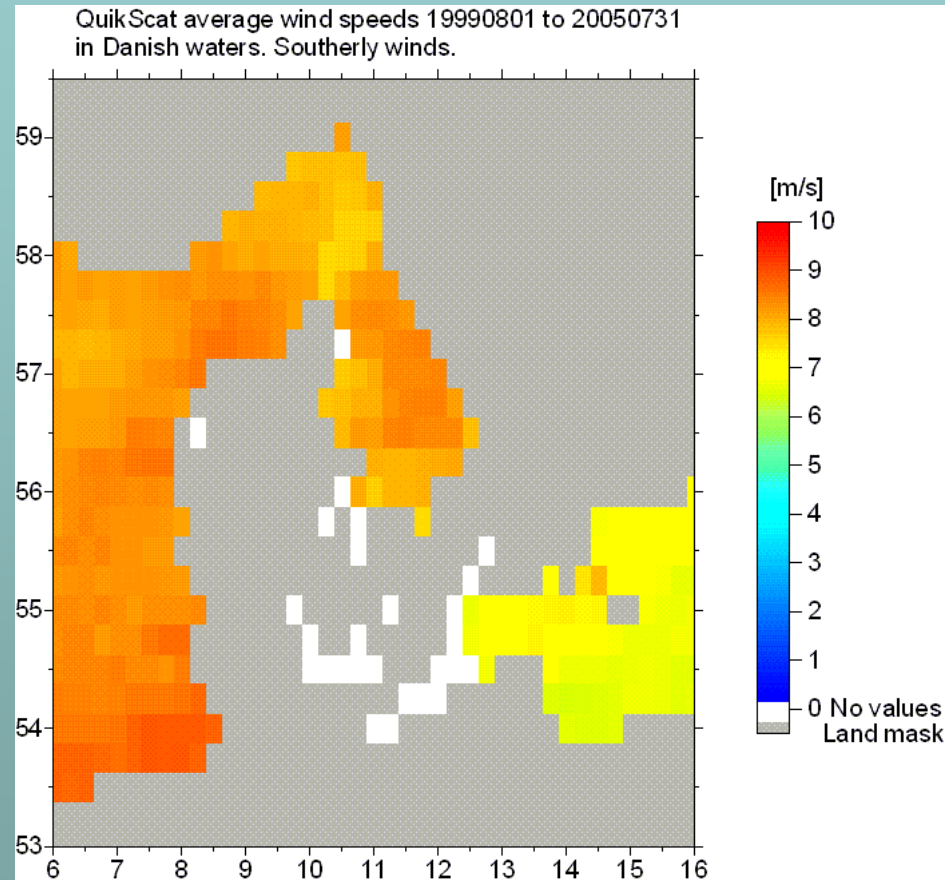
QuikScat results: mean wind speed 5 years



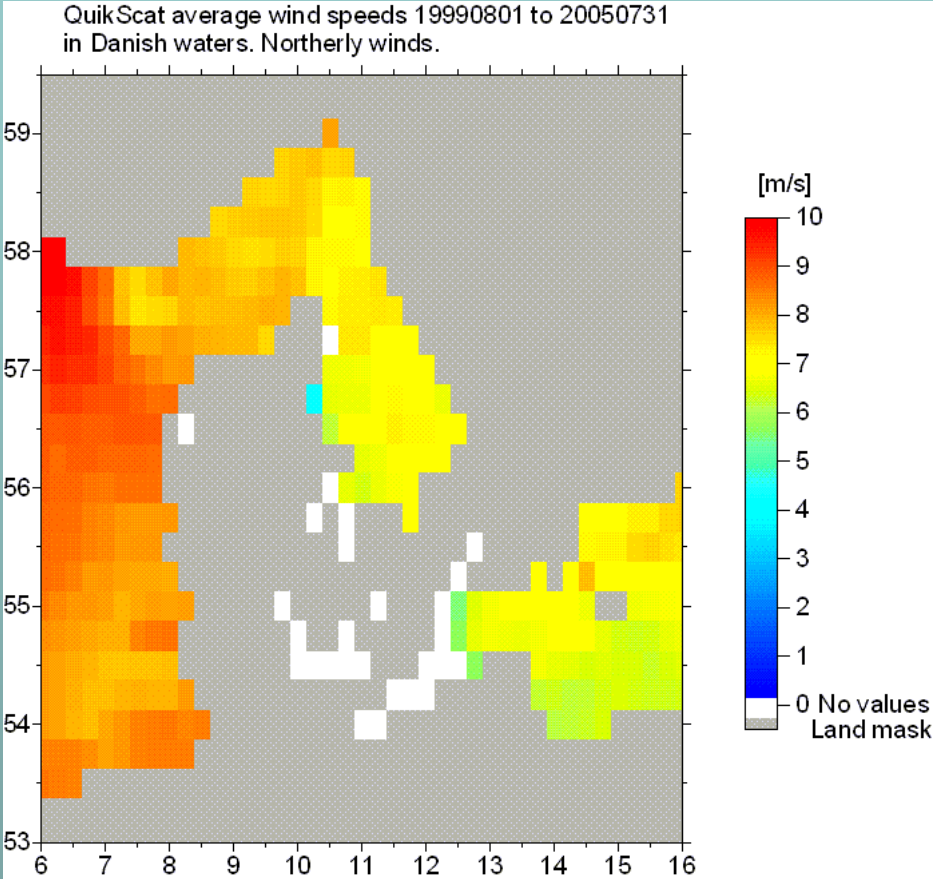
Grid cell:
ca. 25 km

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

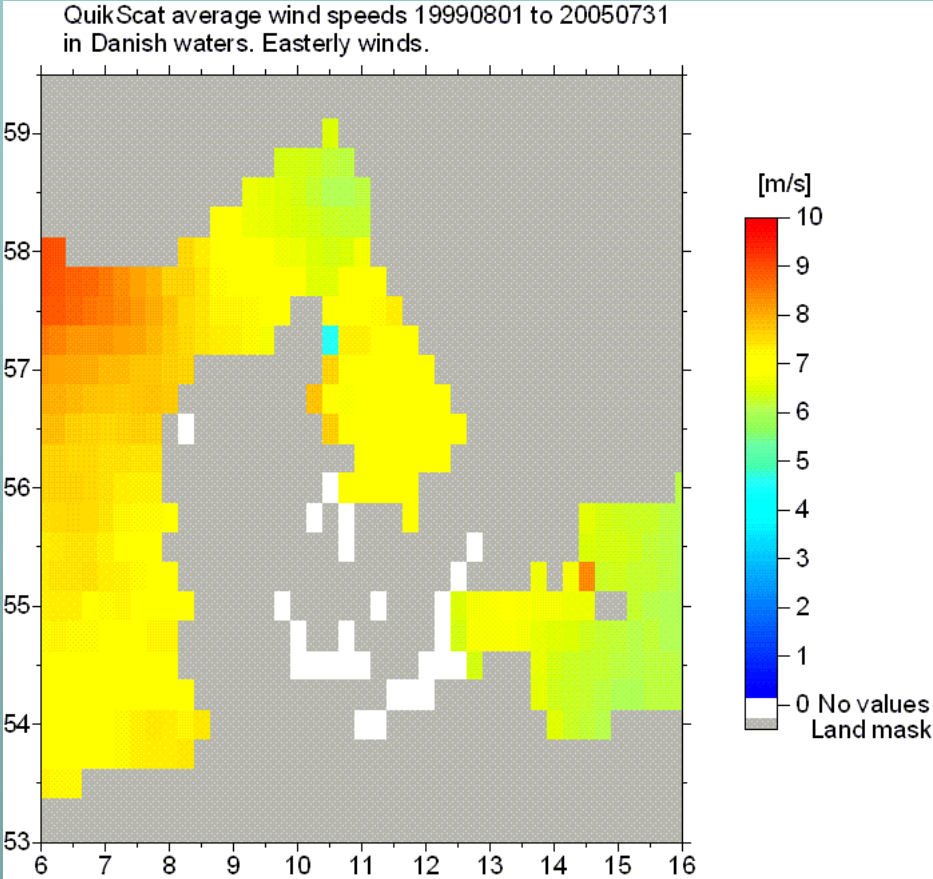
QuikScat results: mean wind speed south



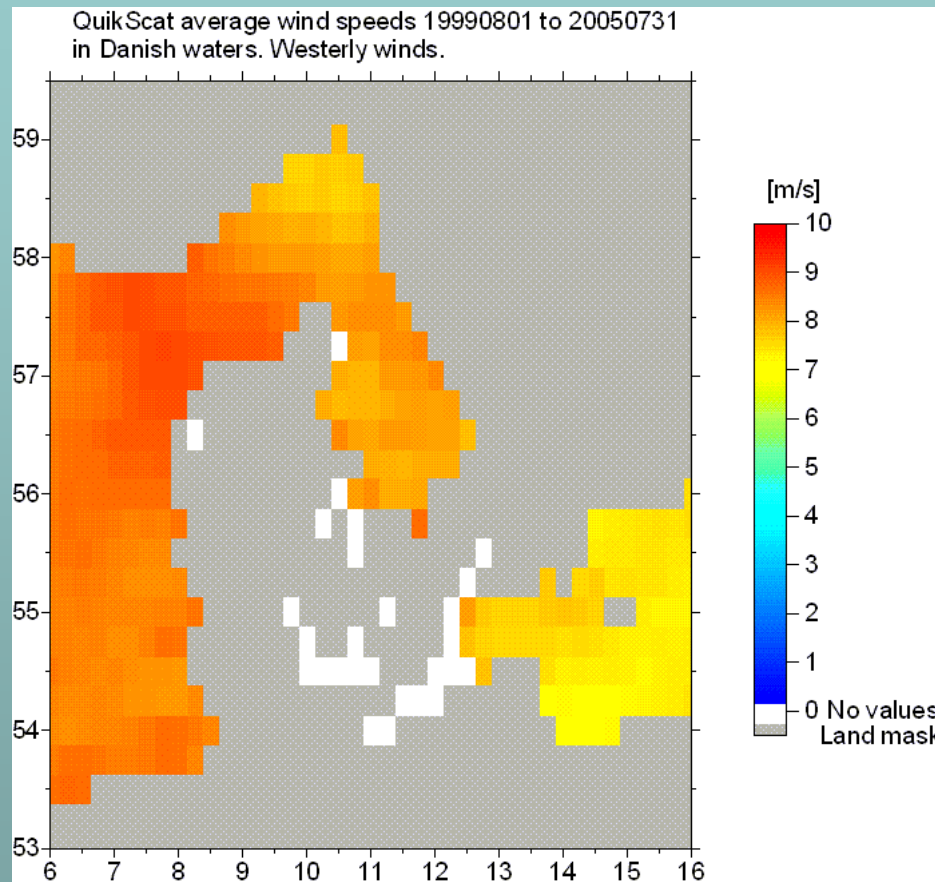
QuikScat results: mean wind speed north



QuikScat results: mean wind speed east

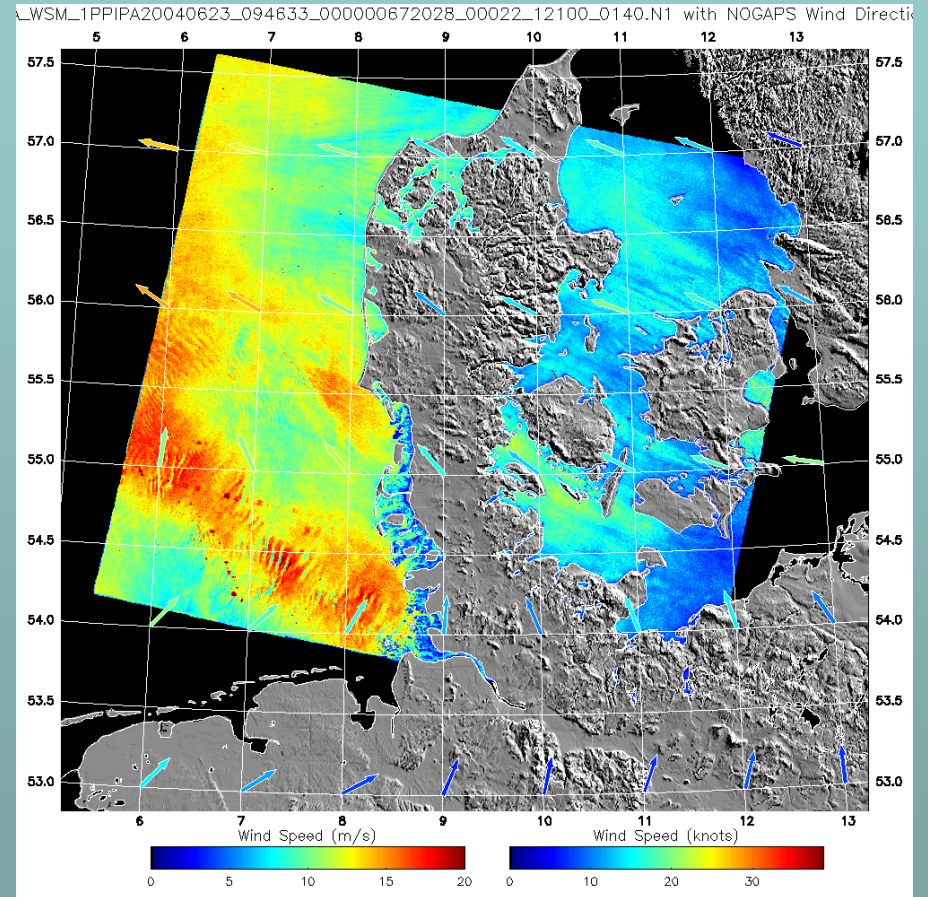
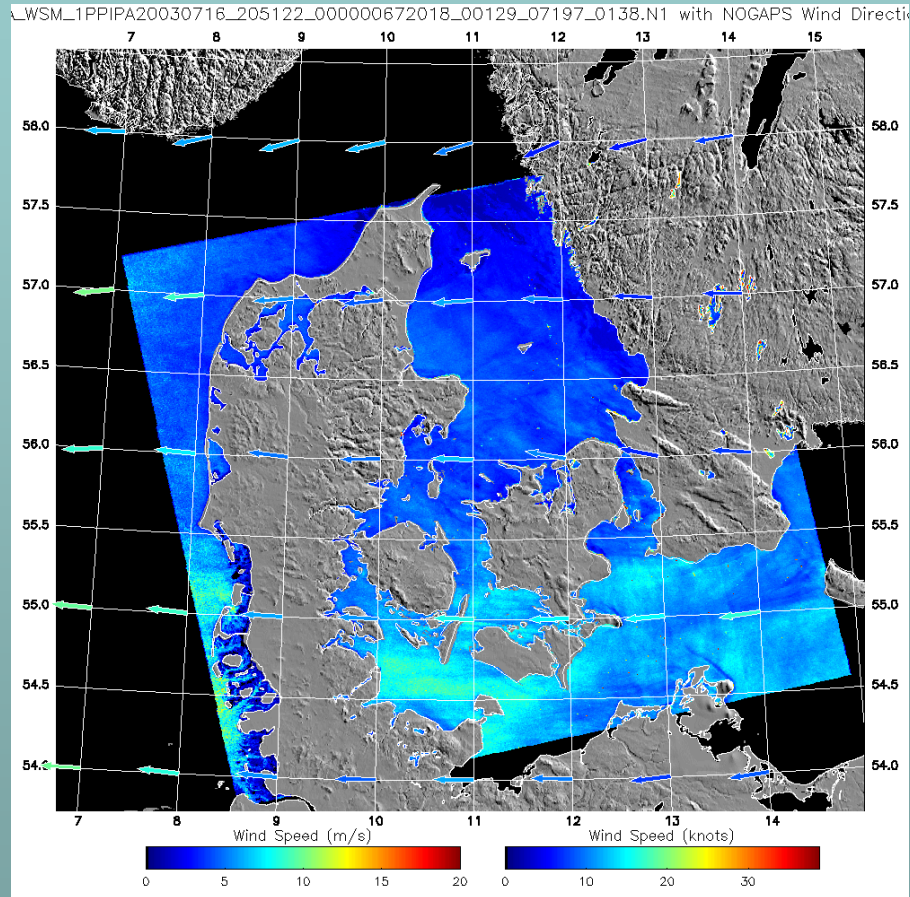


QuikScat results: mean wind speed west



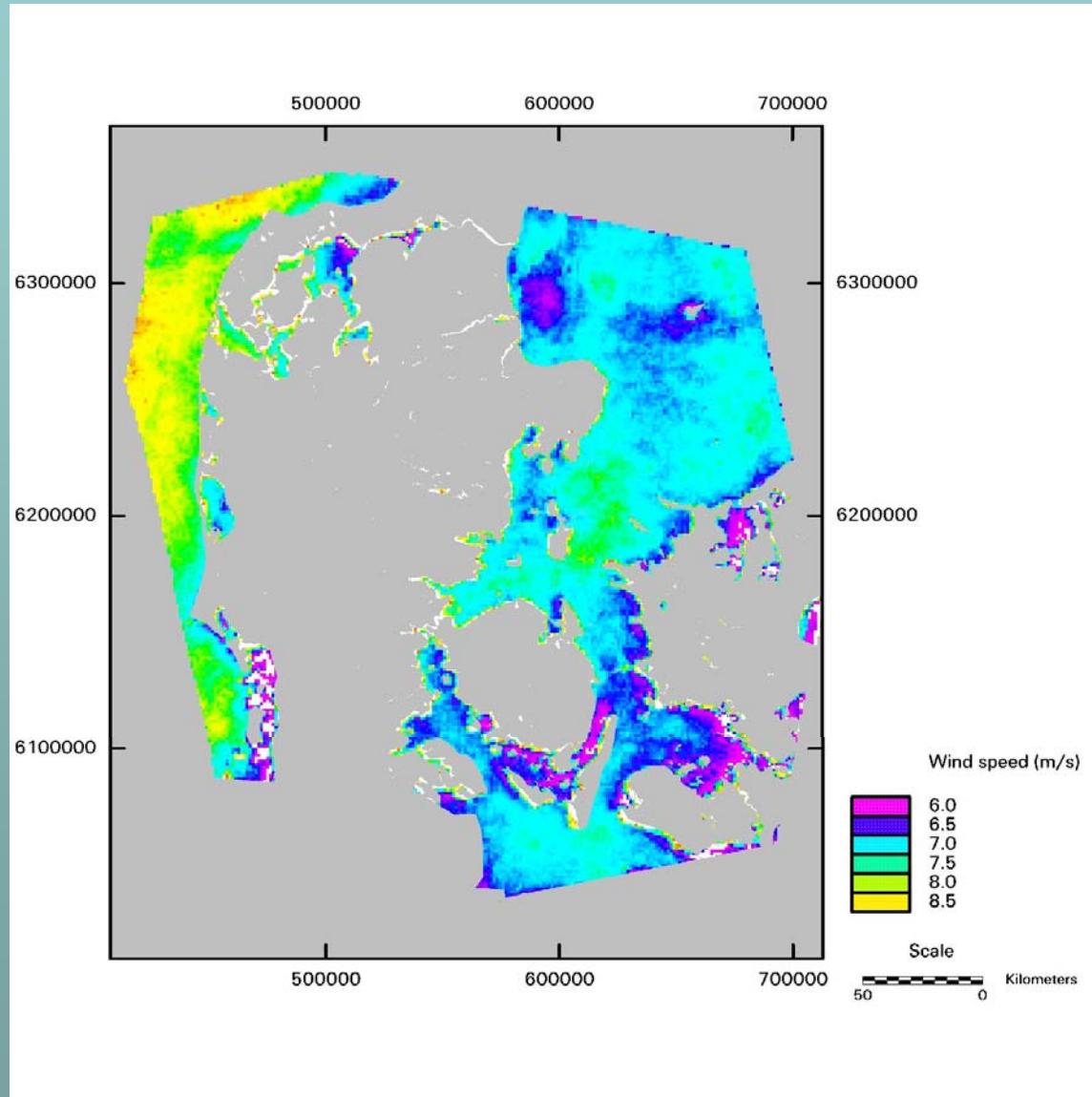
Also available: Weibull A and k per sector
in WASP tab-file format

Envisat WSM: two snap-shots



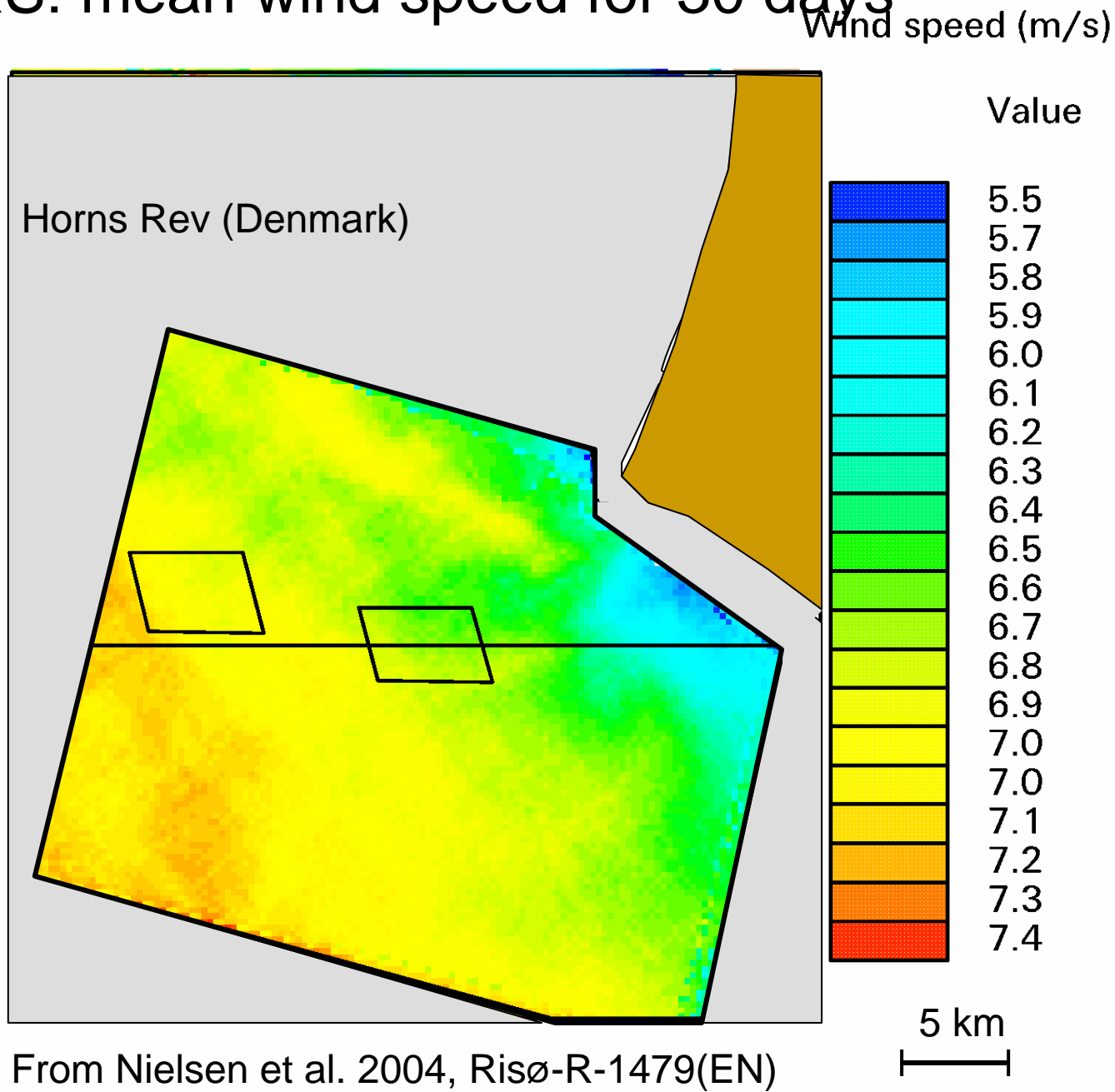
Wind speed maps (Courtesy: JHU-APL)

Envisat WSM: mean wind speed for 20 days



Grid cell:
1.6 km

ERS: mean wind speed for 30 days

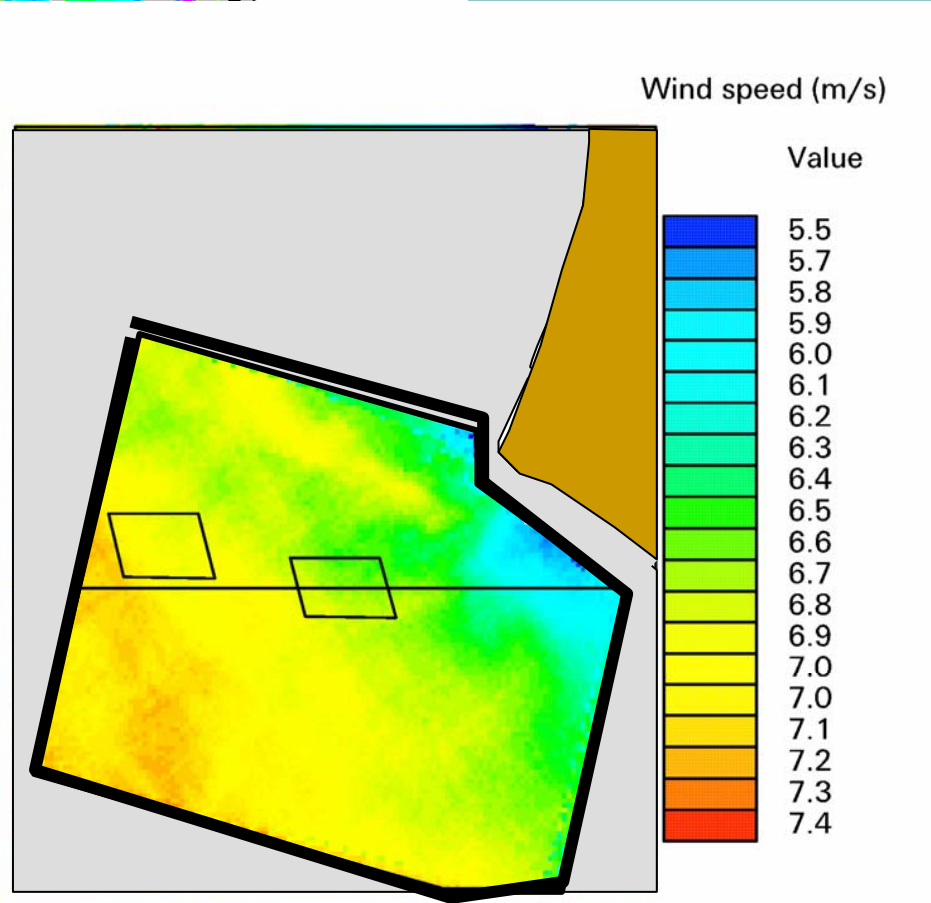
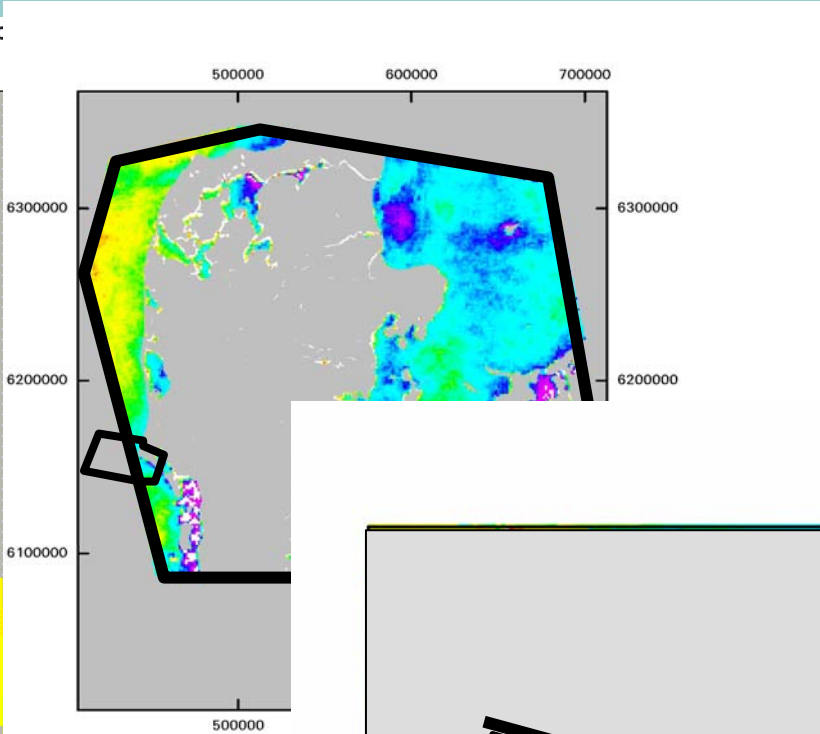
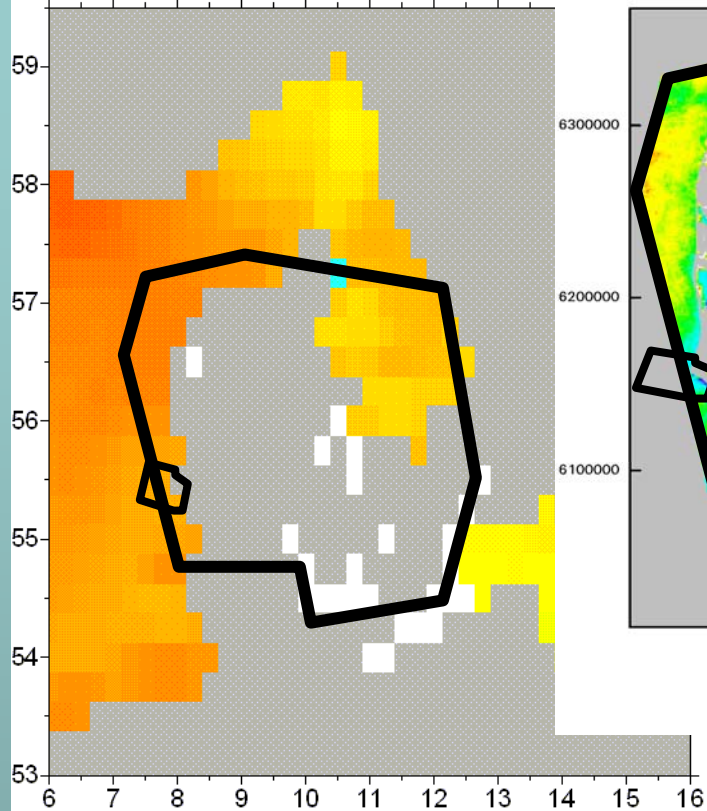


Grid cell:
400 m



Summary

QuikScat average wind speeds 19990801 to in Danish waters. All wind directions.



QuikScat

Envisat WSM

25 km

1.6 km

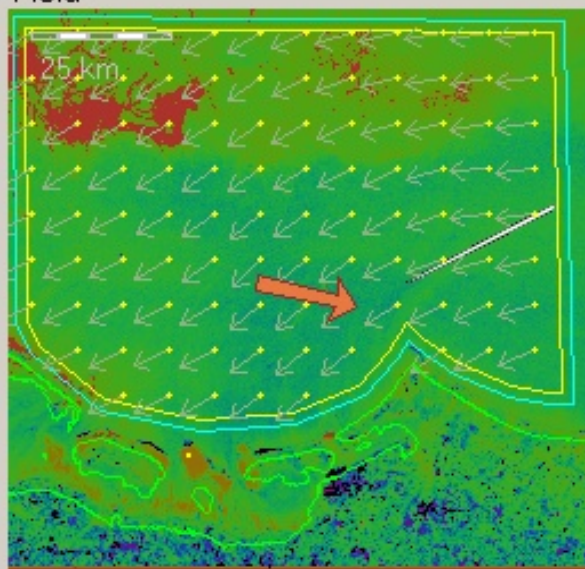
ERS

400 m

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 Coordinates
 Geographic
 UTM
 Longitude
 Turbine hub height (m)
 Show stream
 Show boundary
 Show footprint
 Show coast
 Show north
 Show scale
 Displayed field
 none
 wind speed
 wind direction
 filtered speed
 Footprint contour (%)

List of satellite scenes

- | | |
|--|--|
| <input checked="" type="checkbox"/> 21340_1107_990 | <input checked="" type="checkbox"/> 23509_2493_991 |
| <input checked="" type="checkbox"/> 21777_2482_990 | <input checked="" type="checkbox"/> 24010_2493_991 |
| <input checked="" type="checkbox"/> 21798_1107_990 | <input checked="" type="checkbox"/> 24160_1107_991 |
| <input checked="" type="checkbox"/> 22006_2486_990 | <input checked="" type="checkbox"/> 24346_1107_991 |
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| <input checked="" type="checkbox"/> 23072_1107_990 | <input checked="" type="checkbox"/> 25785_2475_000 |
| <input checked="" type="checkbox"/> 23280_2493_991 | <input checked="" type="checkbox"/> 26014_2486_000 |
| <input checked="" type="checkbox"/> 23344_1107_991 | <input checked="" type="checkbox"/> 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 |

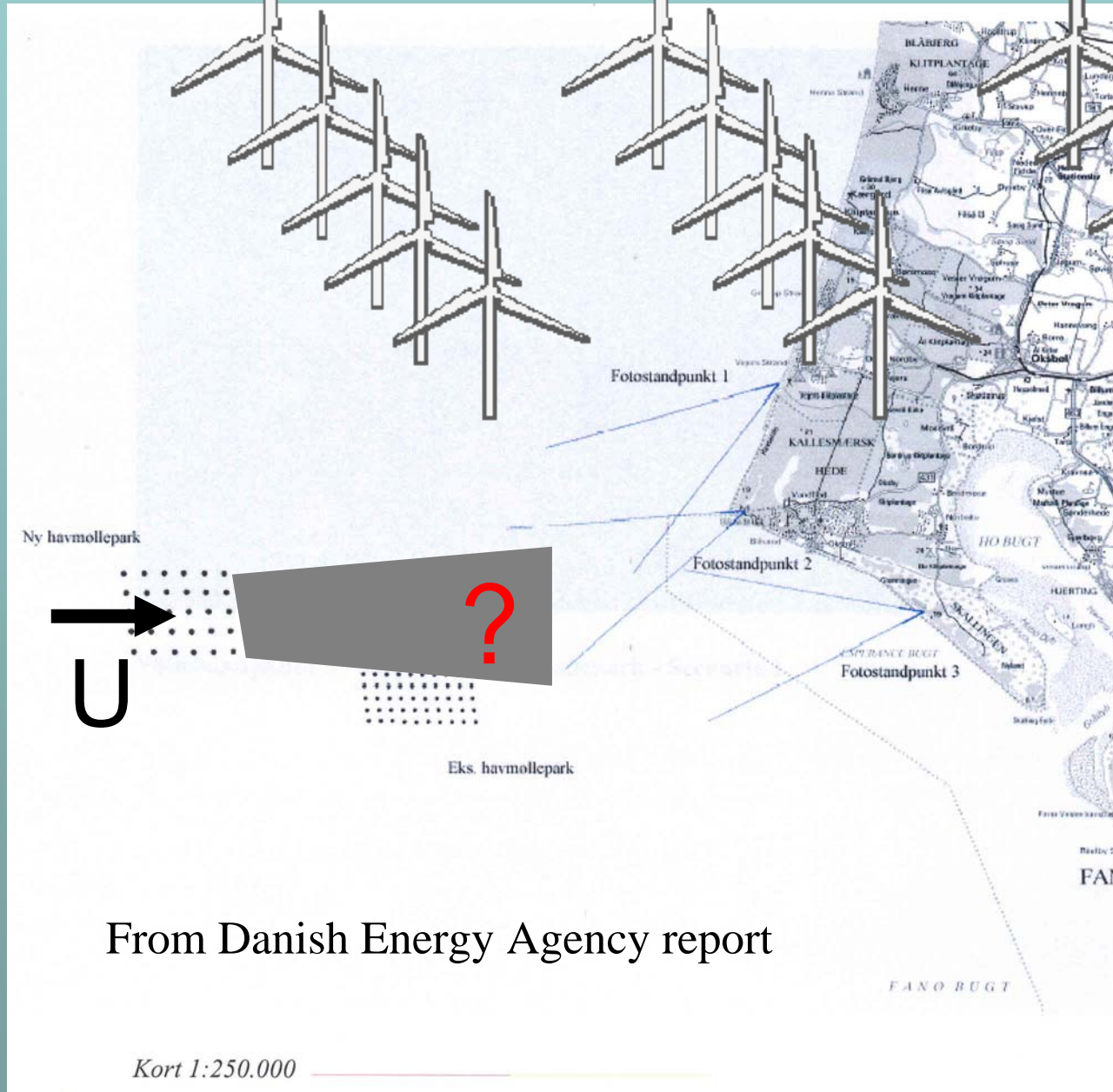
Max Boundary Save Boundary

List of scenes using all data within boundary

- | | |
|---|---|
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| <input type="checkbox"/> 23280_2493_991 | <input type="checkbox"/> 26014_2486_000 |
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Wakes

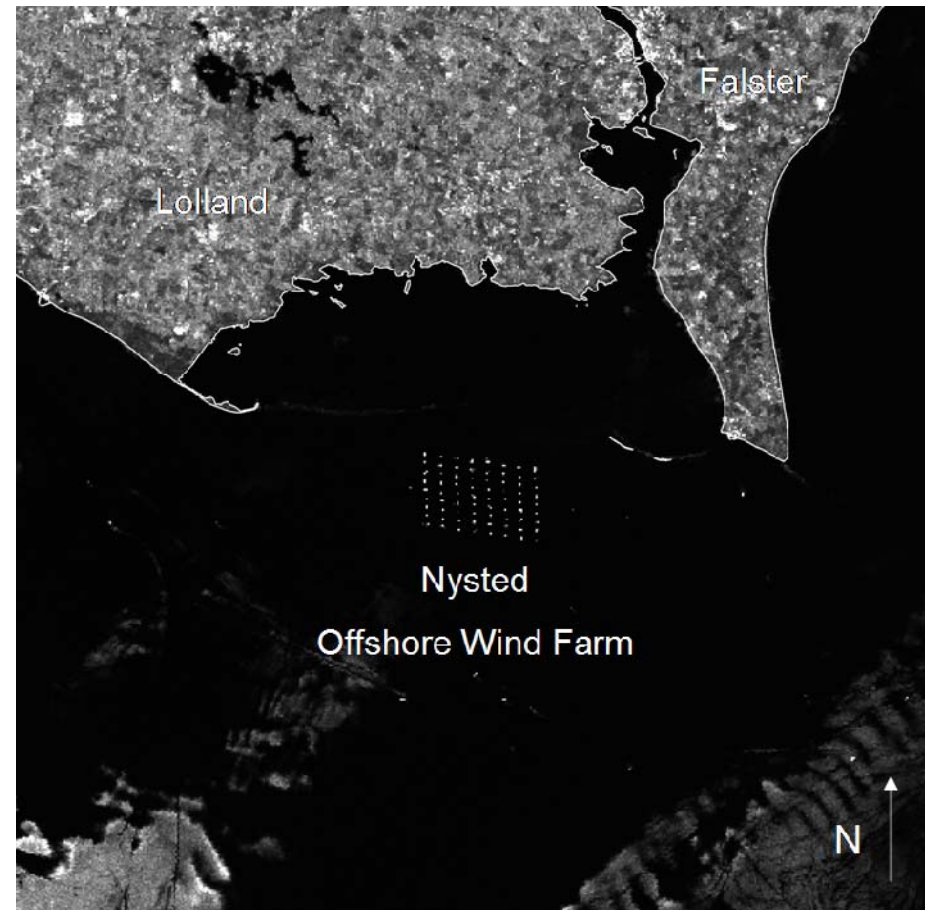
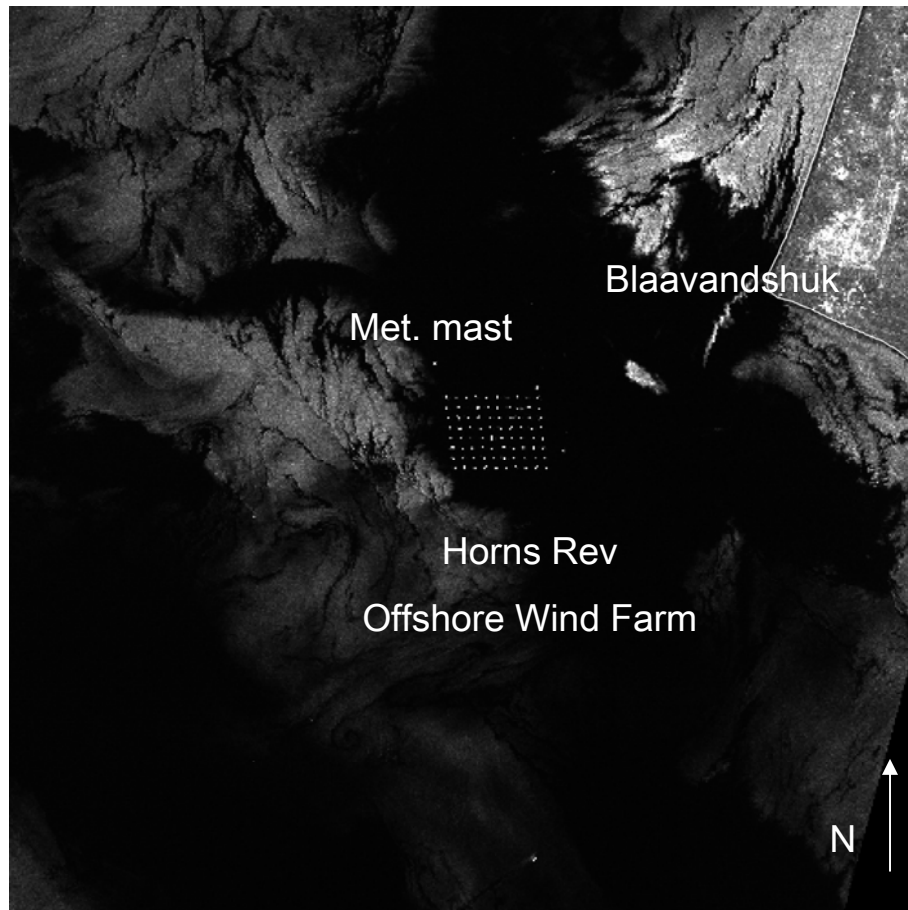
Horns Flev (Denmark)



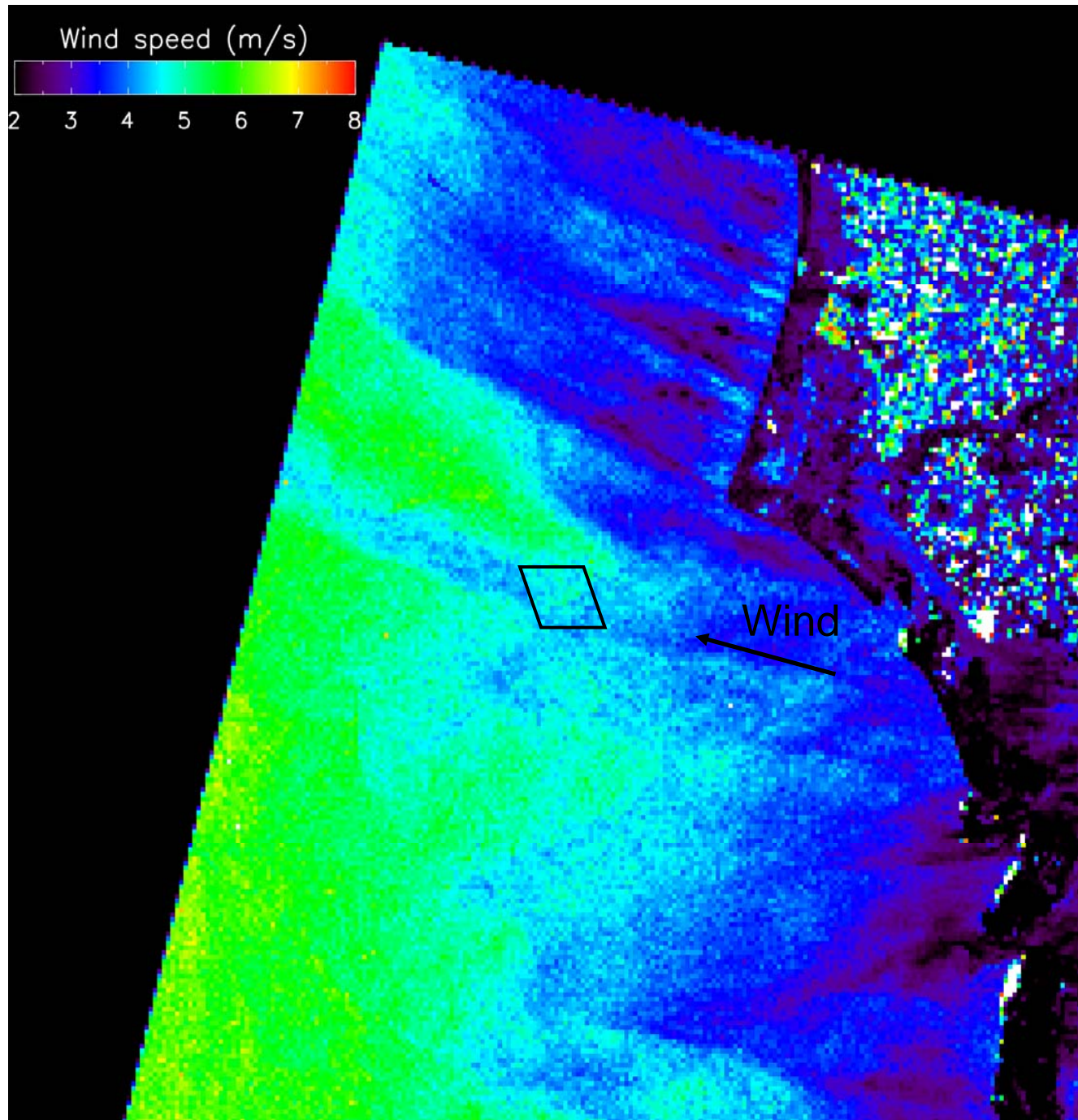
From Danish Energy Agency report

Kort 1:250.000

Study sites: Horns Rev and Nysted

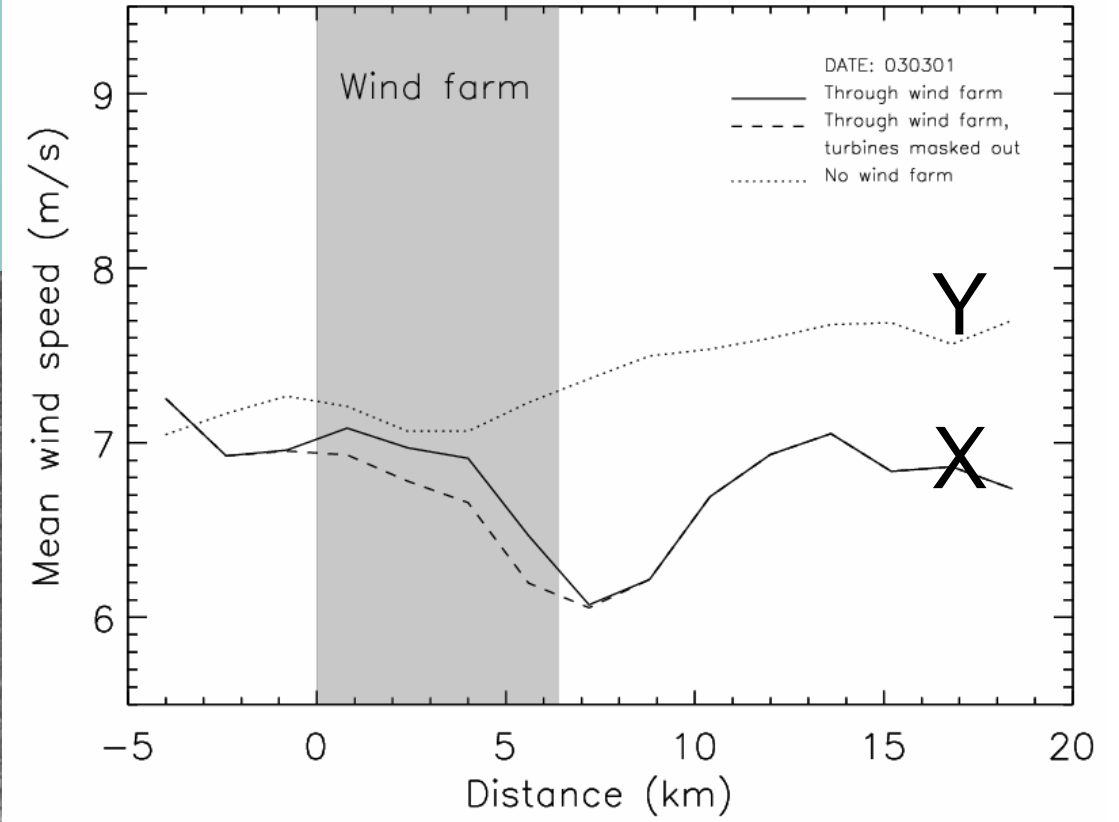
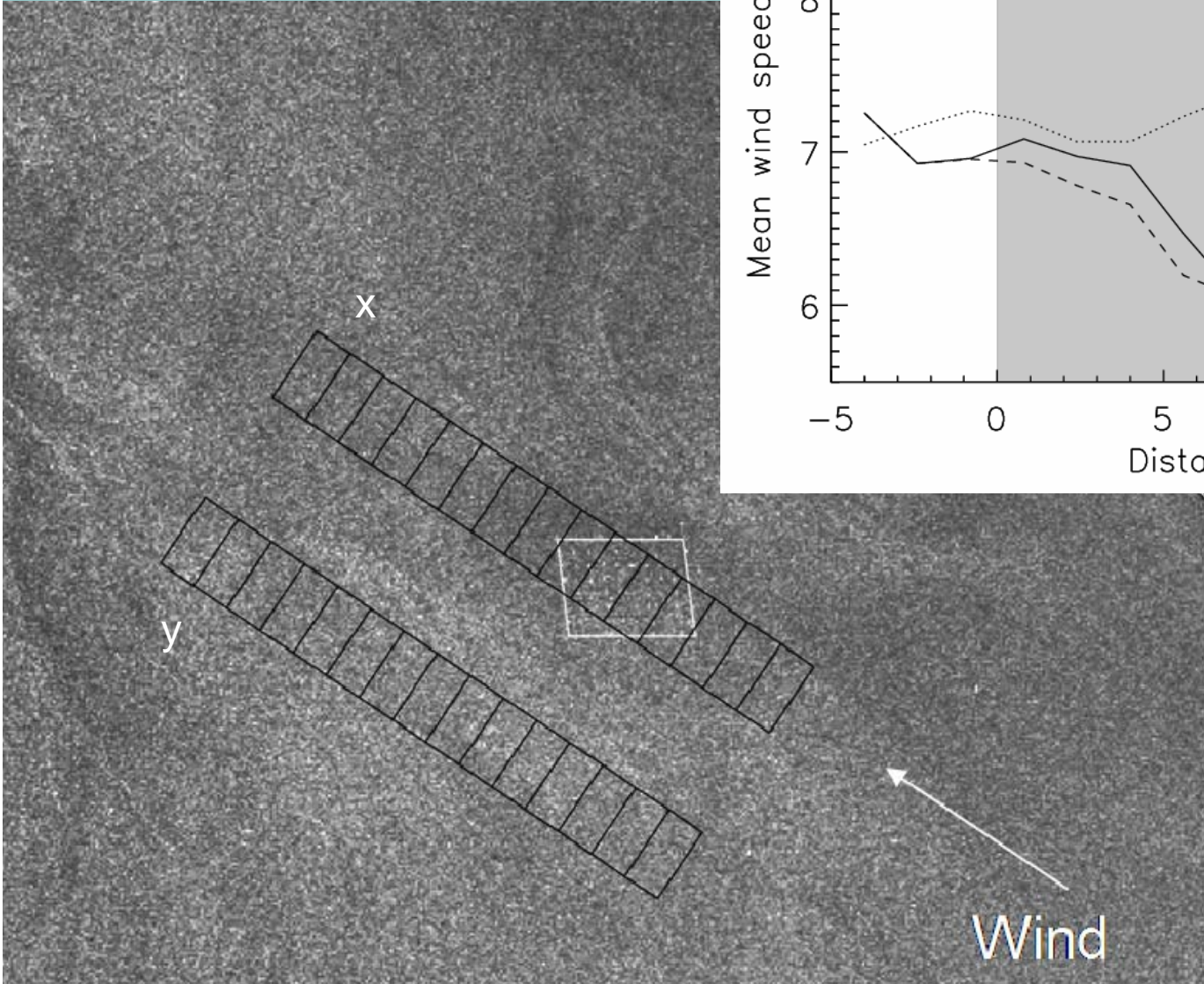


ERS-2 raw images (no wind)



Horns Rev

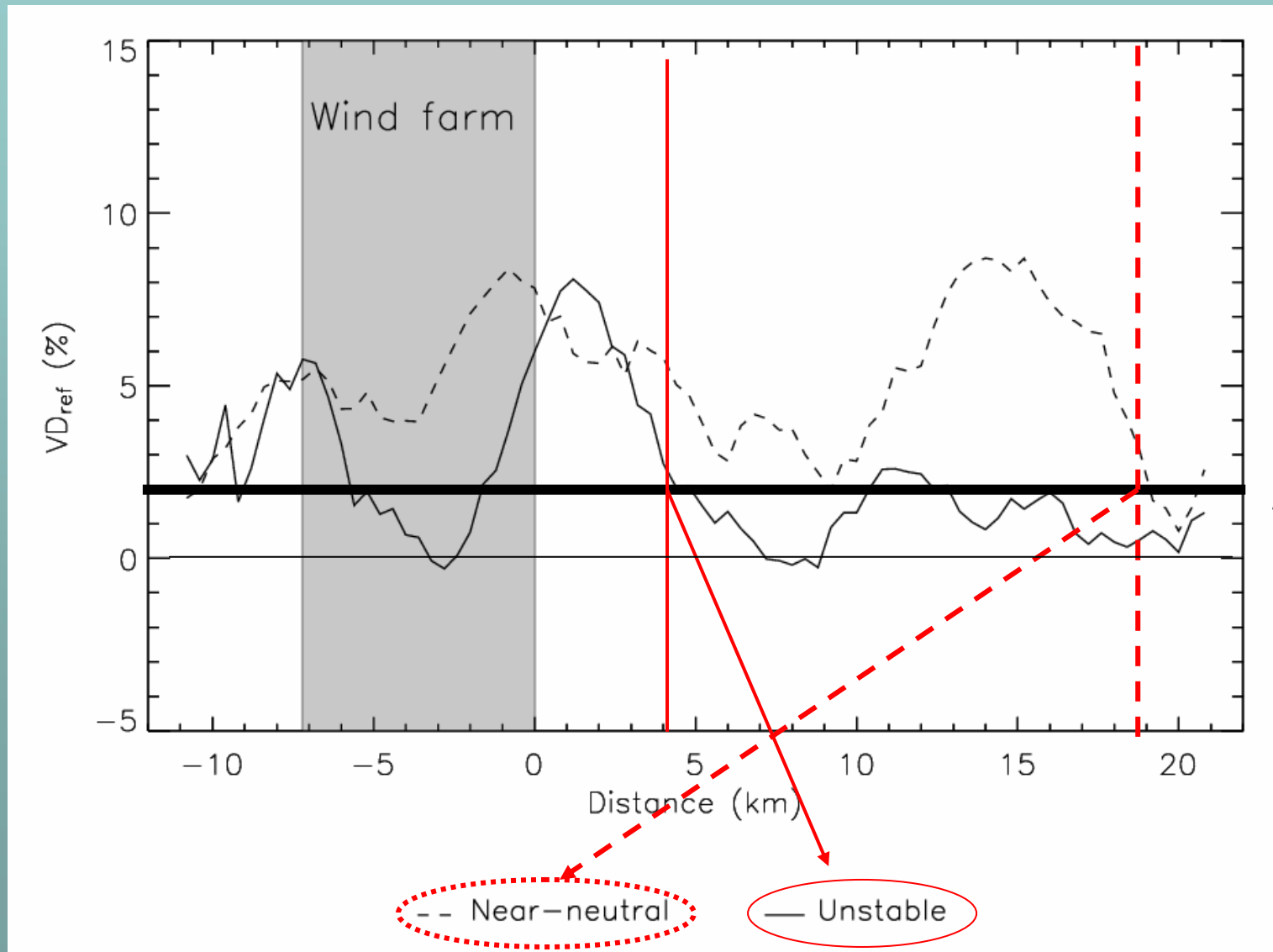
*Wind speed map
from ERS*



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}

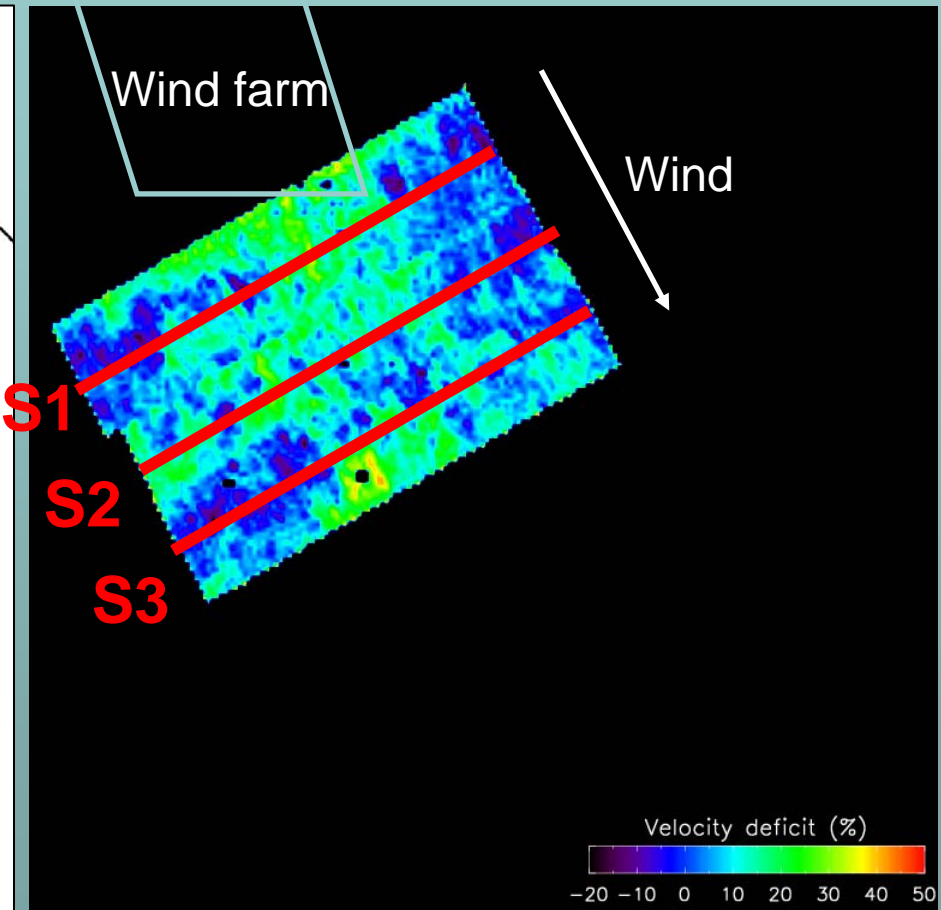
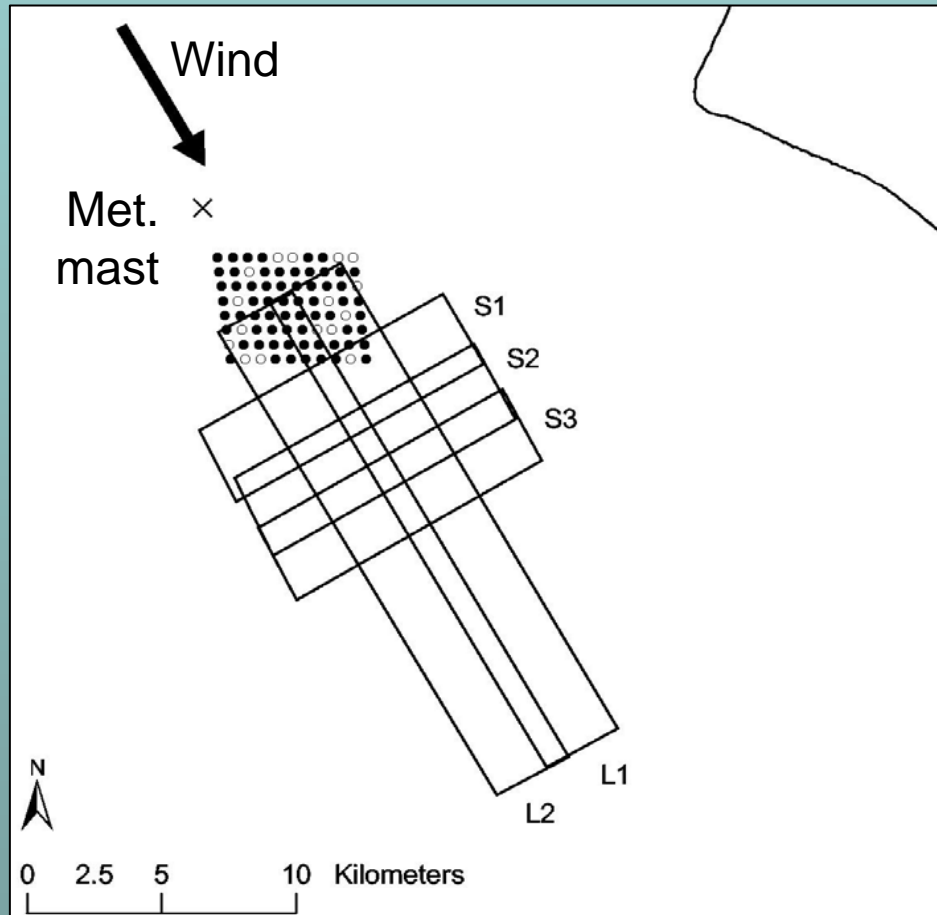
RISØ



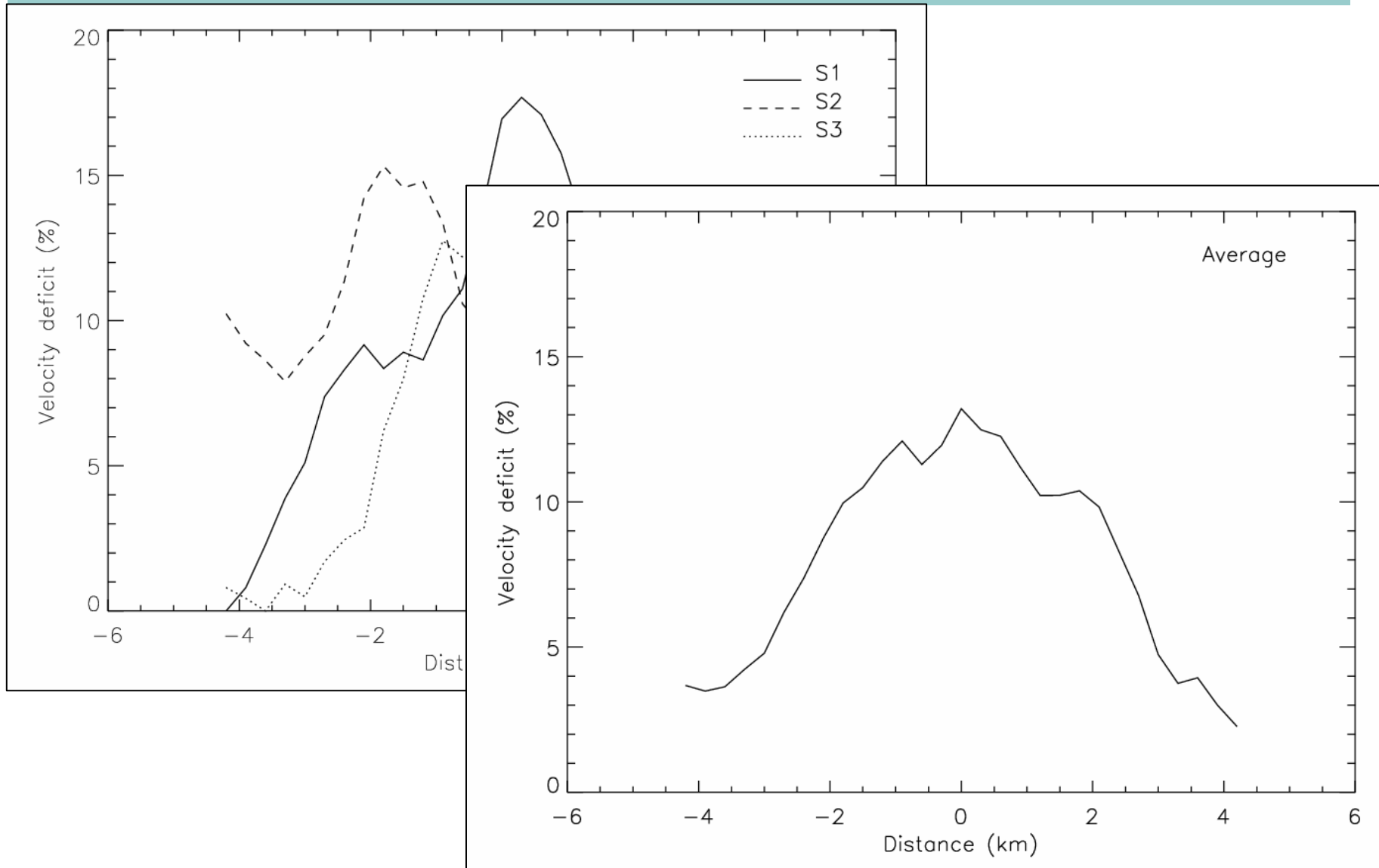
E-SAR at Dornier in Esbjerg (Denmark), 12 October 2003

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.