Spectral analysis of ENVISAT ASAR & QuikSCAT winds

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Introduction

The spectral properties of surface wind fields are a fundamental research topic for oceanic modelling, for estimating extreme winds [2] and as a measure of accuracy for meso-scale, short-term forecasting [1]. For offshore conditions, where in situ measurements are sparse, space-borne observations provide wide spatial coverage of the wind distribution, aiding the understanding of the large scale wind variability.

Direct comparisons between QuikSCAT and ENVISAT ASAR wind fields are limited by differences in the spatial resolution and the approximately 5-hour time lag between overpass times in the North Sea. Spectra derived from ENVISAT ASAR and QuikSCAT near-surface ocean wind fields are investigated over the North Sea. The two sensors offer a wide range of spatial resolutions, from 600 m to 25 km, with different spatial coverage over the area of interest. A sub-domain in the North Sea is chosen, due to the overlap of 87 near-surface wind fields from both sensors.

Early investigations of wind spectra have shown a dependency of the spectral energy on the wave number k; for wave lengths smaller than approximately 400 km, the wind velocity spectra decrease with a $-\mathbf{5/3}$ slope and for the range 1000–3000 km, the decrease has a slope closer to $-\mathbf{3}$ [3]. Different QuikSCAT products showed that in the Pacific Ocean and for wave numbers in the meso-scale and length scales from 50 to 1700 km the slope ranged from -2.2 to -2.4 [4]. For a single 200 m resolution SAR image from ERS-1, a slope around -1.1 was reported for length scales between 100 and 2 km [5].

Data

ENVISAT ASAR

- Radar backscatter σ_0
- Operating frequency: 5.2 GHz
- LECT at 10:00, 22:00
- Repeat cycle: 35 days
- Wind speed retrieval: Johns Hopkins ANSWRS system
- A priori wind directions: NOGAPS 1°, 6-hourly
- Wide Swath Mode (WSM): 150 m resolution

QuikSCAT

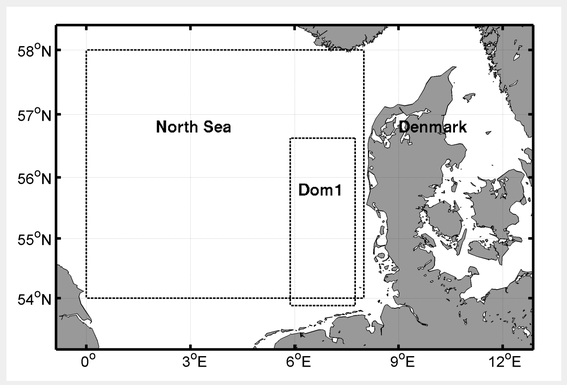
- Radar backscatter σ_0
- Operating frequency: 13.2 GHz
- LECT at 06:00, 18:00
- Repeat cycle: 1 - 2 passes / day
- SeaWinds on QuikSCAT: speed & direction
- **E**quivalent **N**eutral **W**ind 10 m
- 2–20 m s^{-1} –> RMSE 2 m s^{-1}
- RSS L3 gridded product: 25 km resolution

Table: Description of the wind fields used for the spectral analysis. In brackets are the corresponding amounts of QuikSCAT near-surface wind fields from the 10-year archive.

N (10years)	87 (5626)
N per fraction of day (10years)	Morning 48 (2944), Evening 39 (2682)
N per Year	2009: 28, 2008: 26, 2007: 30, 2006: 03
Season (10years)	DJF:23 (1412), MAM:22 (1461), JJA:17 (1419), SON:25 (1334)

Data Quality Control & Methods

- Time-collocation: date and fraction of day
- QuikSCAT Rain-flagging
- Maximum data loss:20% / QuikSCAT pass
- Wind speed spatial series for west-east (zonal), north-south (meridional)
- Linear de-trending –> FFT
- Spectral slopes, Variation from $-5/3$: 100*($-5/3$−slope)/slope



Sub-domain Dom1 and the full North Sea domain

Results

Resolution

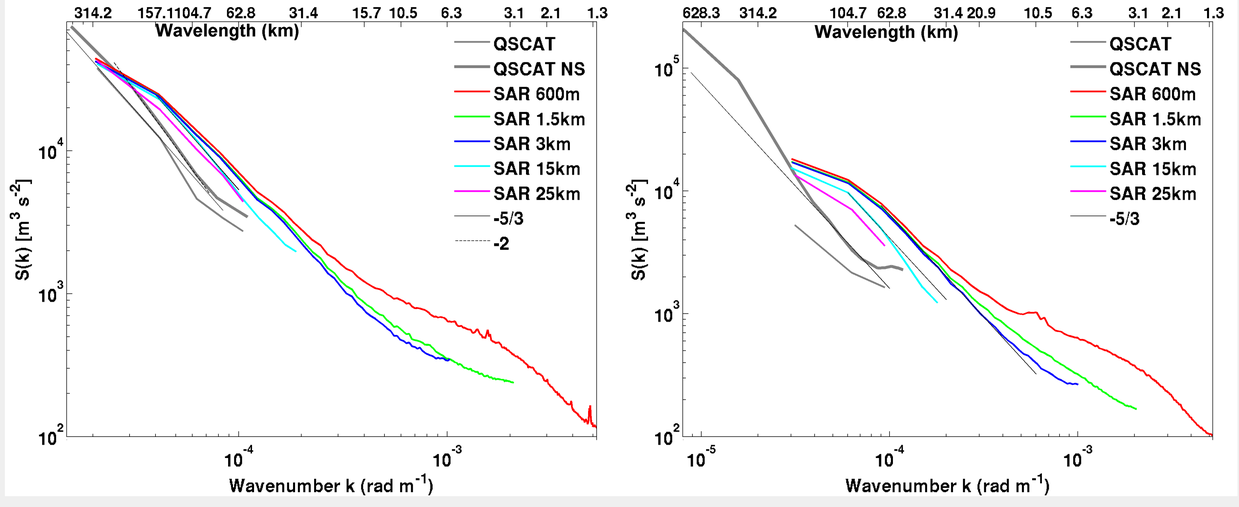


Figure: Spectra averaged in the meridional (North–South) and zonal (West–East) directions, estimated from 87 near-surface wind fields SAR of various resolutions and QuikSCAT. Black lines show the $-5/3$ (solid) and -2 (dashed) slopes.

Sample Size

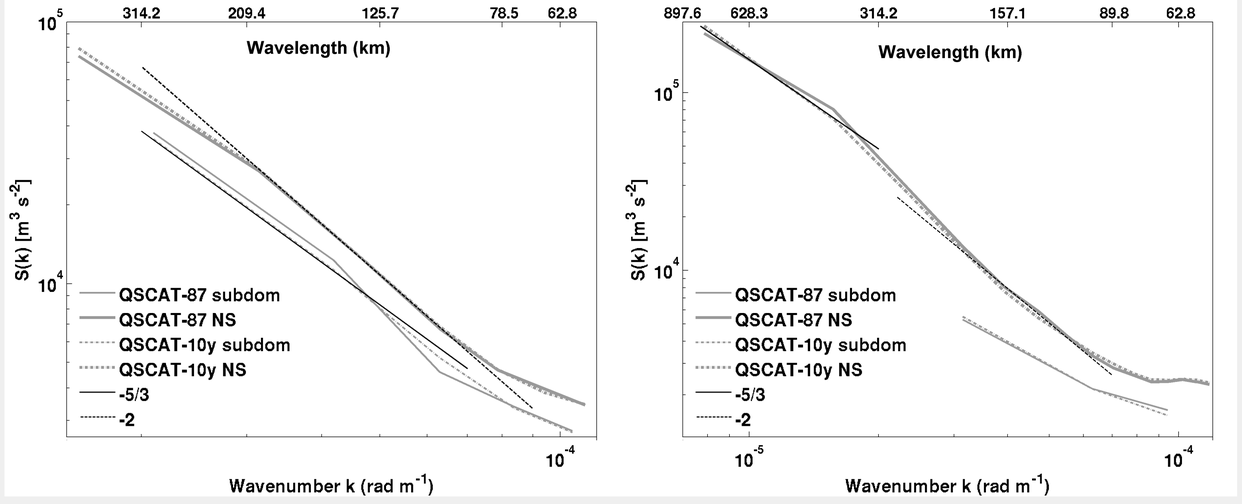


Figure: Spectra averaged in the meridional and zonal directions from 87 (solid lines) vs. 5626 (dashed) QuikSCAT rain-free surface wind fields. Both the Dom1 (thin lines) and the North Sea (thick) study areas are included. Black lines show the $-5/3$ (solid) and -2 (dashed) slopes.

Table: Spectral slopes for SAR and QuikSCAT near-surface wind fields. QuikSCAT spectra for the Dom1 and North Sea (NS) domains, computed from the 87 and 5626 (10y) rain-free wind fields are also shown.

		SAR 600 m	SAR 1.5 km	SAR 3 km	SAR 15 km	SAR 25 km	QSCAT Dom1 (87)	QSCAT Dom1 (5626)	QSCAT NS (87)	QSCAT NS (5626)
Meridional		−0.99	−1.10	−1.32	−1.48	−1.40	−1.7 0	−1.65	−1.65	−1.69
Zonal		−0.99	−1.15	−1.35	−1.47	−1.18	−1.10	−1.18	−1.80	−1.78
Variation from −5/3 (%)	Meridional	−38.1	−31.3	−17.5	−7.5	−12.5	6.2	−3.1	−3.1	5.6
	Zonal	−38.1	−28.1	−15.6	−8.1	−26.3	−31.9	−26.3	12.5	11.2

Conclusions

A significant impact of the spatial resolution was observed, manifested as an increase in spectral density over similar wavenumber ranges as the spatial resolution increased. The mean pectra computed from 87 wind fields are consistent with those obtained from several thousands of samples. QuikSCAT spectral slopes for the mid-latitude region of interest follow the theoretical predicted power law of $-\mathbf{5/3}$. The SAR spectral slopes are shallower than the QuikSCAT ones but become larger as the resolution decreases. The SAR processing at very high resolutions preserves small scale features that are otherwise eliminated through averaging, when the wind retrieval is performed at lower resolutions. Care must be taken for length-scales smaller than 2 km due to speckle noise.

References and Acknowledgments

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