ANALYSIS OF THE ESA WINDSCATTEROMETER CAMPAIGN DATA

G P de Loor

TNO Physics & Electronics Laboratory, The Hague, The Netherlands

ABSTRACT

All data of the ESA windscatterometer campaign as provided by the Central Data Library were analyzed. The data obtained fit in the available empirical model and the parameters of this model were determined. The data set was not only related to the actually measured windspeed at 19.5 m but also to the neutral stability wind U_N.
They are also compared with other data sets.

1. INTRODUCTION

The main campaign of the ESA windscatterometer campaign was executed between January 28 and February 28 1984. For a description the reader is referred to Attema (1). The radar backscatter data (primarily VV polarization) collected by France, Germany, and The Netherlands, were distributed by the Central Data Library (5). As a member of the Scientific Management Team the author analyzed this data set in relation with the surface data (4). The results obtained which are additional to those reported by Attema (2) and Long (3) will be given here.

The experimental data came in two phases: a preliminary issue late in 1984 and a definite issue in the summer of 1985 (5). In this paper the latest issue will be used.

For the analysis the available data were used to find the parameters of the relation

$$\sigma^o = \bar{\sigma}[1 + B_1 \cos(\phi-\phi_1) + B_2 \cos 2(\phi-\phi_2)] \qquad (1)$$

with $\bar{\sigma} = B_0 U^H$.

The parameters are: the exponent H and the coefficients B_0, B_1, and B_2. U is the windspeed measured at a height of 19.5 m. This relation was adopted in an experimenters workshop (6) as being - at least for the moment - the best empirical description available for the radar backscatter as a function of windspeed U and winddirection ϕ. See also (3).

The data sets obtained in Sylt (German Bight) and in Lorient (Atlantic Ocean) were analyzed separately. With the aid of an algorithme developed by Ezraty and Ollitrault (7, 4) it was possible to derive the neutral stability wind U_N (also at 19.5 m, since this height was chosen as reference height for this experiment) and the friction velocity U_* from the available surface data.

2. RESULTS OF THE DATA ANALYSIS

2.1 Determination of the parameters of (1)

Figure 1 gives an example of the results obtained. It gives $\bar{\sigma}$ as a function of the measured windspeed U. With the aid of such plots the exponent H can be determined. Further analysis gives the other parameters of formula (1). The results - using only the data obtained in Lorient (Atlantic Ocean) - are reported in table 1 and the figures 2 and 3. In these two figures they are compared with two SASS models derived from the SEASAT data (8, 9). The values for the exponent H obtained in this campaign lie under those found for the SEASAT

θ degr.	exp. H U	exp. H U_N	B_0 (dB) U	B_0 (dB) U_N	B_1	B_2	$\bar{\sigma}_{10}$ (dB) U	$\bar{\sigma}_{10}$ (dB) U_N
18	0.82	0.88	-5.4	-6.0	0.06	0.16	+2.9	+2.8
25	0.98	1.07	-12.4	-13.7	0.09	0.27	-2.6	-3.0
35	1.18	1.30	-21.0	-22.5	0.16	0.39	-9.2	-9.5
45	1.36	1.48	-27.6	-29.5	0.21	0.45	-14.0	-14.7
55	1.46	1.58	-32.2	-33.6	0.24	0.48	-17.6	-17.8
65	1.45	1.56	-34.0	-35.2	0.28	0.49	-19.5	-19.6

$\phi_1 = \phi_2$ = winddirection

Table 1 Summary of the results

Proceedings of the 3rd International Colloquium on Spectral Signatures of Objects in Remote Sensing, Les Arcs, France, 16—20 Dec. 1985 (ESA SP-247)

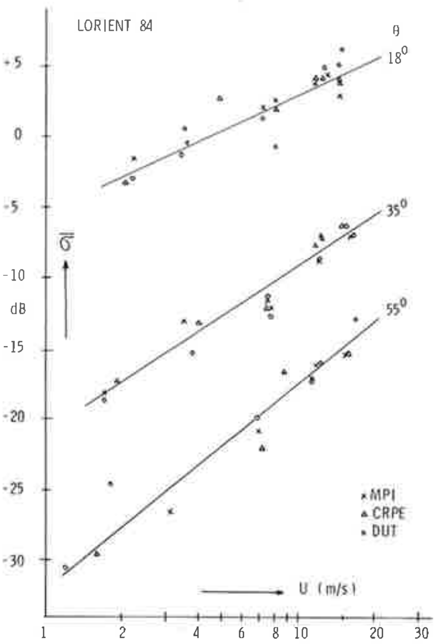

Figure 1 $\bar{\sigma}$ versus windspeed U for the incidence angles 18 °, 35 ° and 55 °

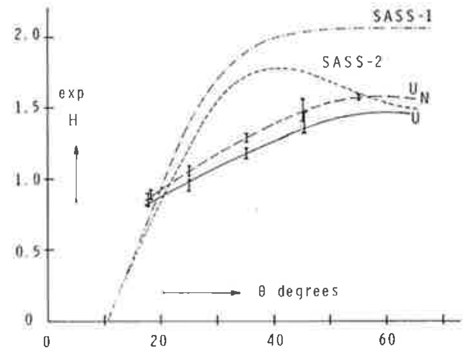

Figure 2 The exponent H versus incidence angle as obtained for both U and U_N compared with the values obtained for two SEASAT models

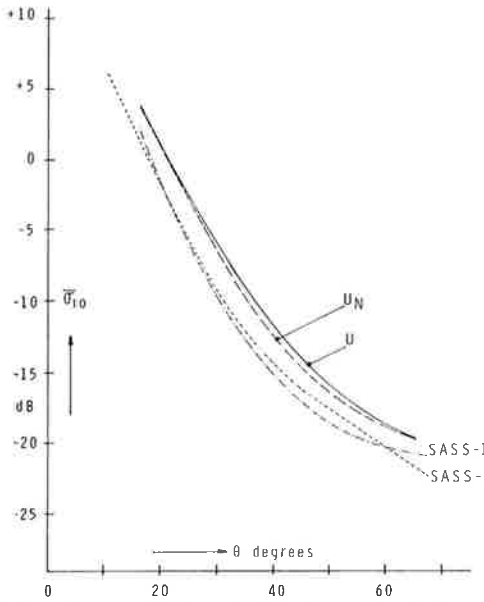

Figure 3 $\bar{\sigma}_{10}$ values ($\bar{\sigma}$ for U = 10 m/s) versus incidence angle obtained for both U and U_N compared with those obtained for two SEASAT models

scatterometer (which uses the K-band) indicating a slightly smaller sensitivity of the radar backscatter for variations in windspeed in the C-band than in the K-band (figure 2).

The values for the exponent H obtained for U_N - the neutral stability wind - are higher than those obtained for U. This is due to the fact that during practically all experiments the meteorological conditions were unstable. In such a situation U_N will be higher than U. For this data set this is between 0.3 and 0.5 m/s. Similar variations in windspeed lead to larger fluctuations in log U at lower windspeeds than at higher windspeeds and so to an increase in H.

Instead of B_0, $\bar{\sigma}_{10}$ - the value for $\bar{\sigma}$ at a windspeed U = 10 m/s - is given in figure 3. The values for $\bar{\sigma}_{10}$ obtained in the C-band are higher than those found for SEASAT, indicating an average increase of the backscatter of between 2 and 3 dB with regard to the K-band.

2.2 Comparison with data obtained at other frequencies

A comparison with data obtained at other frequencies is also possible through the model of Wright (10). Applying first order scattering theory he gave the following relation for the sea echo in terms of the mean-squared spectrum of the sea:

$$\sigma^o(\theta) = 4\pi\ k^4 \cos^4\theta\,|g_{ij}(\theta)|\,S(2k \sin\theta, 0) \qquad (2)$$

where S is the two-dimensional wave number spectrum density of the sea surface roughness, $k = 2\pi/\lambda$ with λ the radar wavelength, θ the incidence angle, and $g_{ij}(\theta)$ are the first-order scattering coefficients; the indices i and j denote the polarization of the incident and backscattered radiation, respectively. Through (2) it is possible to infer the wave number spectrum S(K) from σ^o data ($K = 2k \sin\theta$). The relation $S(K) = A.K^{-\alpha}$ indeed fits the available data (11) with α varying between 3.5 and 4.5 depending on windspeed.

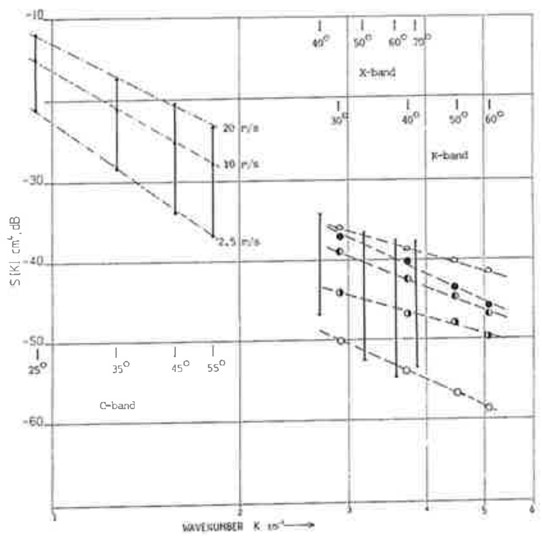

Fig. 4 Ocean wave number spectrum as inferred from σ^o_{VV} (upwind) data compared with those from other sources: X-band, tower data after (11); K-band: after (12). After ref. 10 and 11.

In figure 4 taken from ref. 11 S(K) for the C-band as obtained in this campaign is compared with data from other sources (11, 12).
Average values as obtained in this campaign for the windspeeds 2.5, 10, and 20 m are plotted for upwind conditions. It can then be seen that the campaign data fit in the general picture.

2.3 Comparison of the data obtained in Lorient and Sylt

Having the data of Lorient (Atlantic Ocean) separate from those obtained in Sylt (North Sea) it is possible to compare the two sets. This is done in figure 5. These results could suggest that the backscatter data obtained in Sylt lie under those obtained in Lorient. More experiments and data are necessary, however, before more concrete conclusions can be drawn.

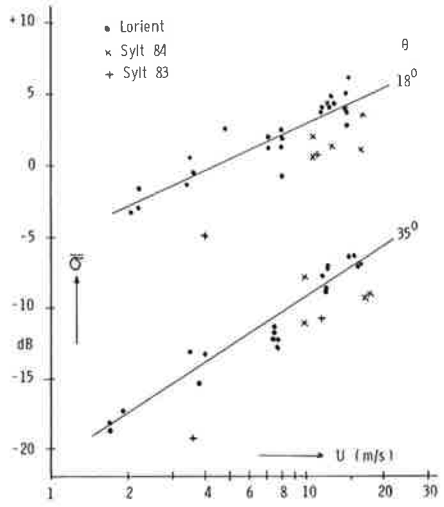

Fig. 5 Comparison of the data obtained in Lorient (Atlantic Ocean; dots) and Sylt (North Sea; crosses)

2.4 Accuracy

An investigation was also made to see to what accuracy the available data set can give the windspeed. The following procedure was used. Boundaries were plotted in the graphs of figure 1 ($\bar{\sigma}$ versus log U) in such a way that nearly all values found for $\bar{\sigma}$ lie between them. This was also done for plots of $\bar{\sigma}$ versus U. The boundaries so obtained show that the total possible variation in windspeed as derived from this data set is in the order of ± 2 m/s.

2.5 Remarks

Considering the results reported a remark is necessary. Secondary factors which may influence the results as the influence of currents, varying water temperatures, waveheight, the angle between winddirection and wavedirection, were not (yet) taken into account. The total range of windspeeds met in this experiment was limited and a possible better relation of the radar backscatter with the friction velocity U* in stead of with the windspeed at 19.5 m also requires further research. Some of these effects can be studied using this data set. This will be done by the individual investigators. Other require further experimentation. As a whole, however, a good data set was obtained and is now available to ESA for the further implementation of its C-band windscatterometer in the ERS-1.

3. CONCLUSIONS

1. The data set obtained in the ESA windscatterometer campaign fits in the available empirical model. The parameters for this model were determined.
2. The possible variation in windspeed as can be derived from this data set is in the order of ± 2 m/s.
3. Further experiments will be necessary to finalize the values for the model parameters when the actual scatterometer flies in the ERS-1.
4. The values obtained for the exponent H (giving the winddependency) are somewhat lower than those found for the K-band scatterometer of SEASAT, which means a slightly lower sensitivity for windspeed in the C-band.
5. On the other hand, the values for the NRCS σ^0 are a 2 dB higher than in the K-band.

4. REFERENCES

1. Attema, E.P.W., An experimental campaign for the determination of the radar signatures of the ocean at C-band, This Proceedings, pp.

2. Attema, E.P.W., Airborne and tower-based scatterometry during the PROMESS and TOSCANE-T experiments, This Proceedings, pp.

3. Long, A.E, Towards a C-band radar sea echo model for the C-band scatterometer, This Proceedings, pp.

4. Ezraty, R., Campaign PROMESS 84, TOSCANE-T - in situ measurements, This Proceedings, pp.

5. Rompelman, O., ESA C-band scatterometer campaign, Data processing Final Report, Delft, 1985.

6. Workshop Report C-band Scatterometer Campaign, Toulouse 12-16 November 1984, ESA, Ref.No. ORM/JCM/EA/dK.

7. Ezraty, R. and Ollitrault, M., Estimation de la vitesse de frottement à la surface de la mer à partir de valeurs de vitesse du vent et des températures de l'air et de l'eau, IFREMER report, May 1, 1984.

8. Wentz, F.J. et al., A model function for ocean radar cross sections at 14.6 GHz, J. Geophys. Res., vol. 90, No. C3, pp. 3689-3704, May 20 1984.

9. Schroeder, L. et al., The relationship between windvector and NRCS used to derive SEASAT-A satellite scatterometer winds, J. Geophys., Res., vol. 87, No. C5, pp. 3318-3336, April 30, 1982.

10. Wright, J.W., A new model for sea clutter, IEEE Trans. Antennas and Propagation Vol. AP-16, pp. 217-223, 1968.

11. De Loor, G.P., Tower-mounted radar backscatter measurements in the North Sea, J. Geophys. Res., vol. 88, No. C19, pp. 9785-9719, Nov. 20, 1983.

12. Jones, W.L. et al., Aircraft measurements of the microwave scattering signature of the ocean, IEEE-Trans. Antennas Propagation vol. AP-25, pp. 52-61, 1977.