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REPORT OF THE WORKSHOP ON

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of workshop on assimilation of satellite wind and wave data in numerical weather and wave prediction models

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B6 The influence of wave-ripple interactions in wind-scatterometer algorithms

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In the scatterometer algorithm used for SEASAT it is assumed that the backscattering cross section σ^0 is a function of only the local wind speed U (at 19.5 m height, after correction for stability), the incidence angle θ and the azimuthal angle ϕ of the radar relative to the wind direction. A good approximation to the measurements under this restriction is given by the model

$$\sigma^0 = A_0(U,\theta)[1 + A_1(U,\theta)\cos\phi + A_2(U,\theta)\cos 2\phi] \qquad (1)$$

(The tabular SASS-model for SEASAT actually differed from this expression, but this is immaterial for the following discussion.)

The second harmonic term essentially reflects the directional distribution of the short backscattering ripples. Since the ripples tend to be aligned with the local wind, the Bragg backscatter is greater in the upwind and downwind direction than in the crosswind direction. The upwind and downwind contributions from the second harmonic term are the same. This corresponds to the response of a radar which sees only an effectively frozen, unmodulated ripple field.

The first harmonic term describes the upwind-downwind asymmetry of the backscattering cross section. This asymmetry can arise only through an asymmetrical structure of the short backscattering ripples or - generally regarded as the more likely mechanism - by the modulation of the backscattering ripples by longer waves (cf. Fig. 1). Thus the coefficient A_1

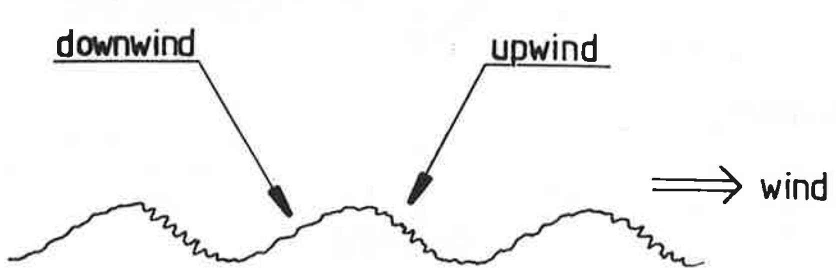

Fig. 1: Upwind-downwind asymmetry of σ^0 due to ripple-long wave interactions

may be expected to depend on the two-dimensional spectrum $F(f,\phi_w)$ of long waves (f = frequency, ϕ_w = wave propagation direction). The assumption that A_1 depends only on the local wind field is justified only if the long wave field represents a fully developed windsea, in which case the spectrum is indeed determined solely by the windspeed. However, this will not be the case in general, and the first harmonic coefficient should therefore be regarded as a function $A_1 = A_1(u, \theta, \phi, F(f,\phi_w))$. Models exist for calculating the coefficient A_1 for a given spectrum and wind vector from the spectral energy balance equation of the short ripples (cf. Iwata, 1983; Feindt et al., 1986).

An estimate of the order of magnitude of the errors incurred by ignoring the long-wave dependence in the backscattering model is given in Figs 2 - 4.

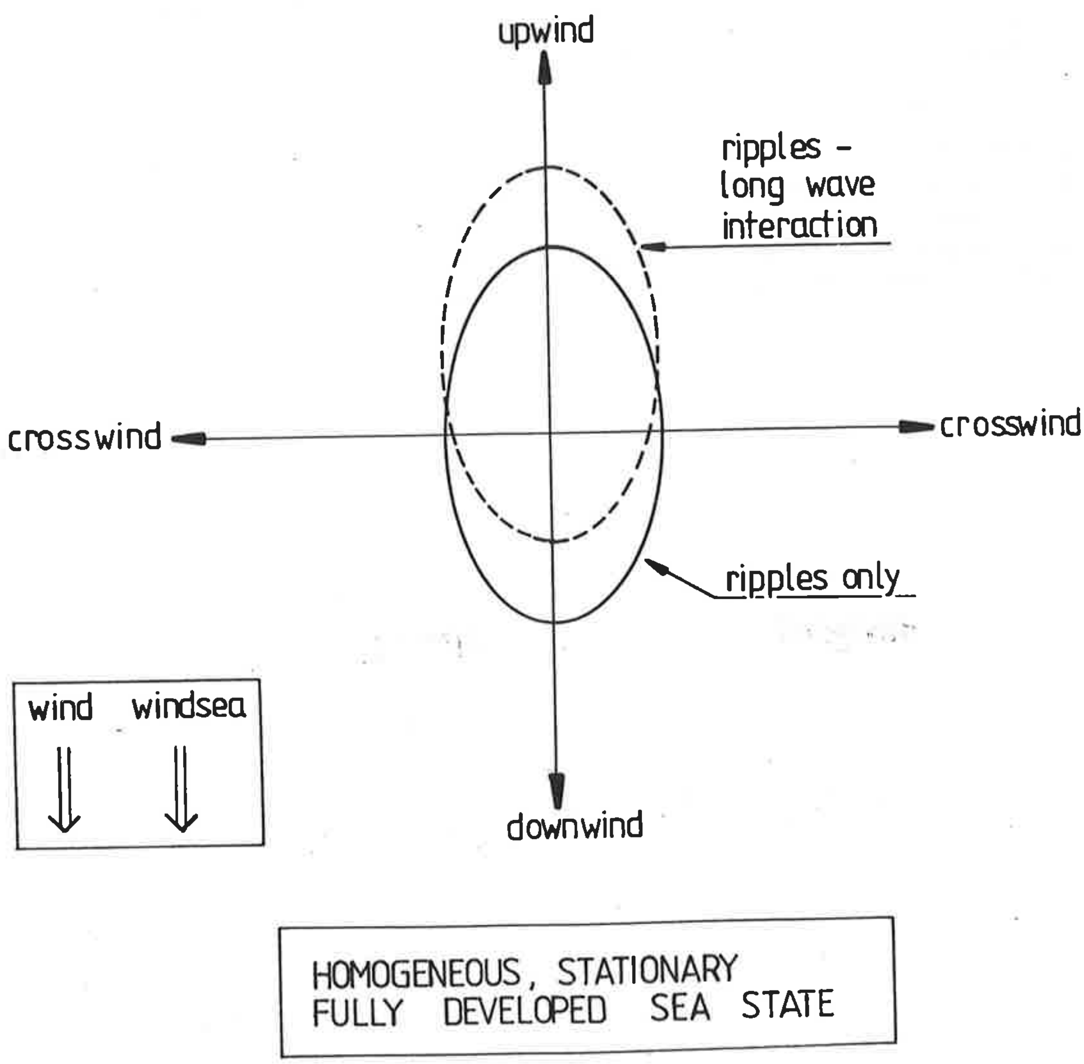

Fig. 2: Polar diagram of azimuthal dependence of σ^0 with and without ripple long-wave interactions for case of fully developed windsea.

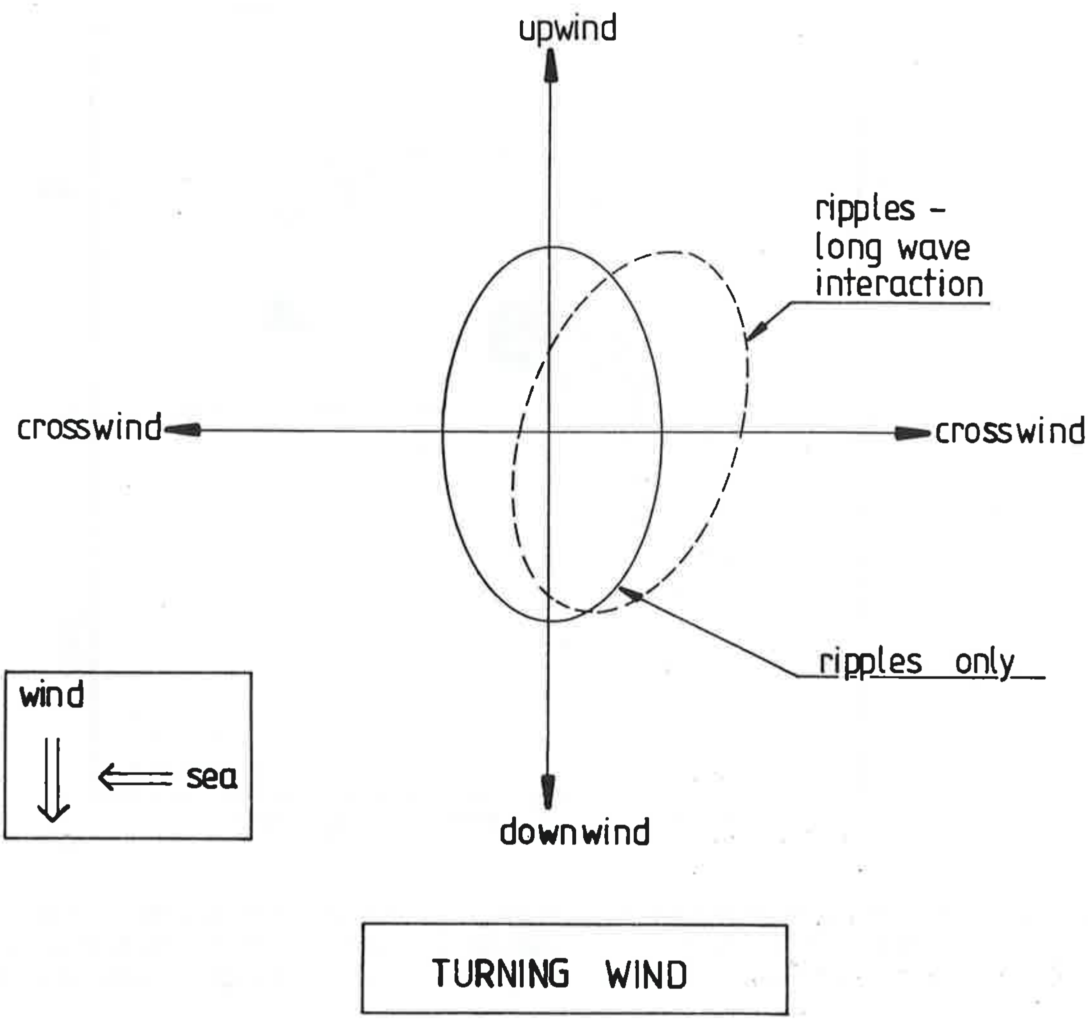

Fig. 3: **Polar diagram of azimuthal dependence of σ^0 with and without ripple long-wave interactions for the case of a windsea propagating orthogonal to the local direction (frontal or small-scale storm or hurricane situation).**

Fig. 2 shows the azimuthal dependence of the cross-section for the case of a windsea aligned with the wind. Fig. 3 shows the azimuthal distribution for the case of a wave field propagating at 90° to the local wind direction, as would be typically found behind a front or in an intense storm. (Fig. 4, from Hasselmann et al., 1986, gives such an example for a hurricane. The two-dimensional wave spectrum predicted with the WAM model is seen to be turned 90° relative to the wind direction.) It is assumed that the coefficient A_1 is aligned with the local mean wave direction. (It is also assumed that A_2 is turned by 20°, since the long wave-short wave interactions can be shown to

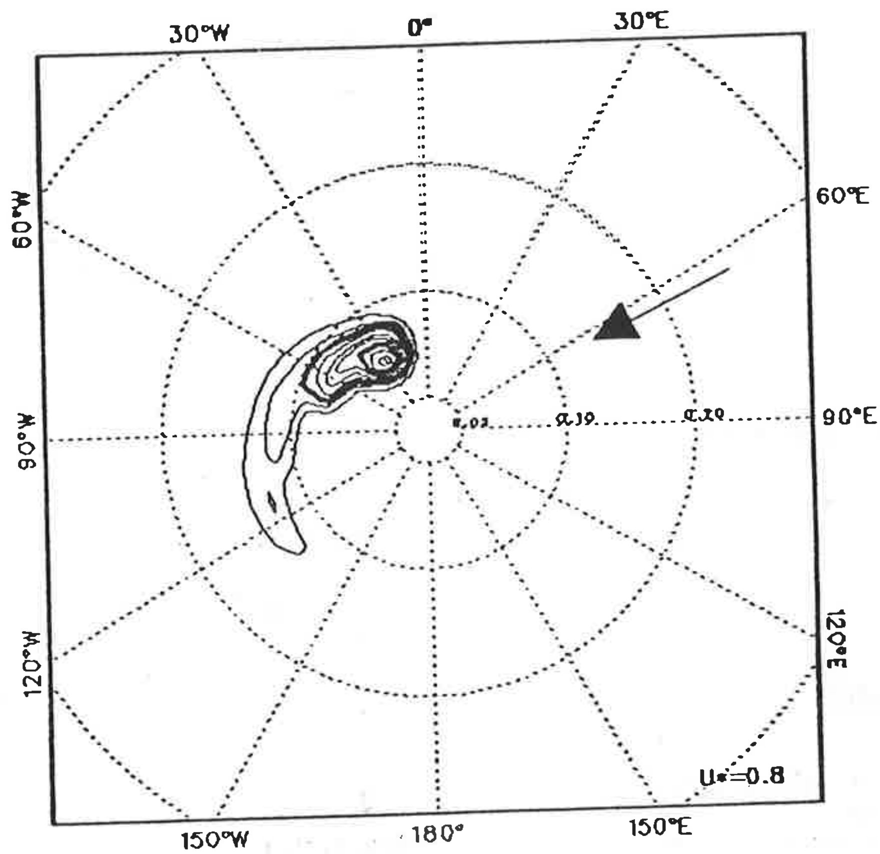

Fig. 4: 2d wave spectrum (frequency-direction polar isoline plot) predicted in a hurricane by the WAM model. The arrow indicates the local wind direction, which is turned 90° relative to the principal wave propagation direction (from Hasselmann et al., 1986).

affect also the second harmonic term to second order.) The differences in wind vector extracted by the scatterometer algorithm for the two cases is shown in Fig. 5. The algorithm assumes a model of the form (1). (The wind extraction computations were carried out by A. Long using the ESTEC C-band model.) The errors are generally of order 10 % in the wind speed and 30° in direction. Although significantly smaller errors may be expected under average wind conditions, errors of this magnitude do not appear unrealistic for windfields of high spatial variability, which are just the conditions for which the highly resolving scatterometer is potentially most valuable.

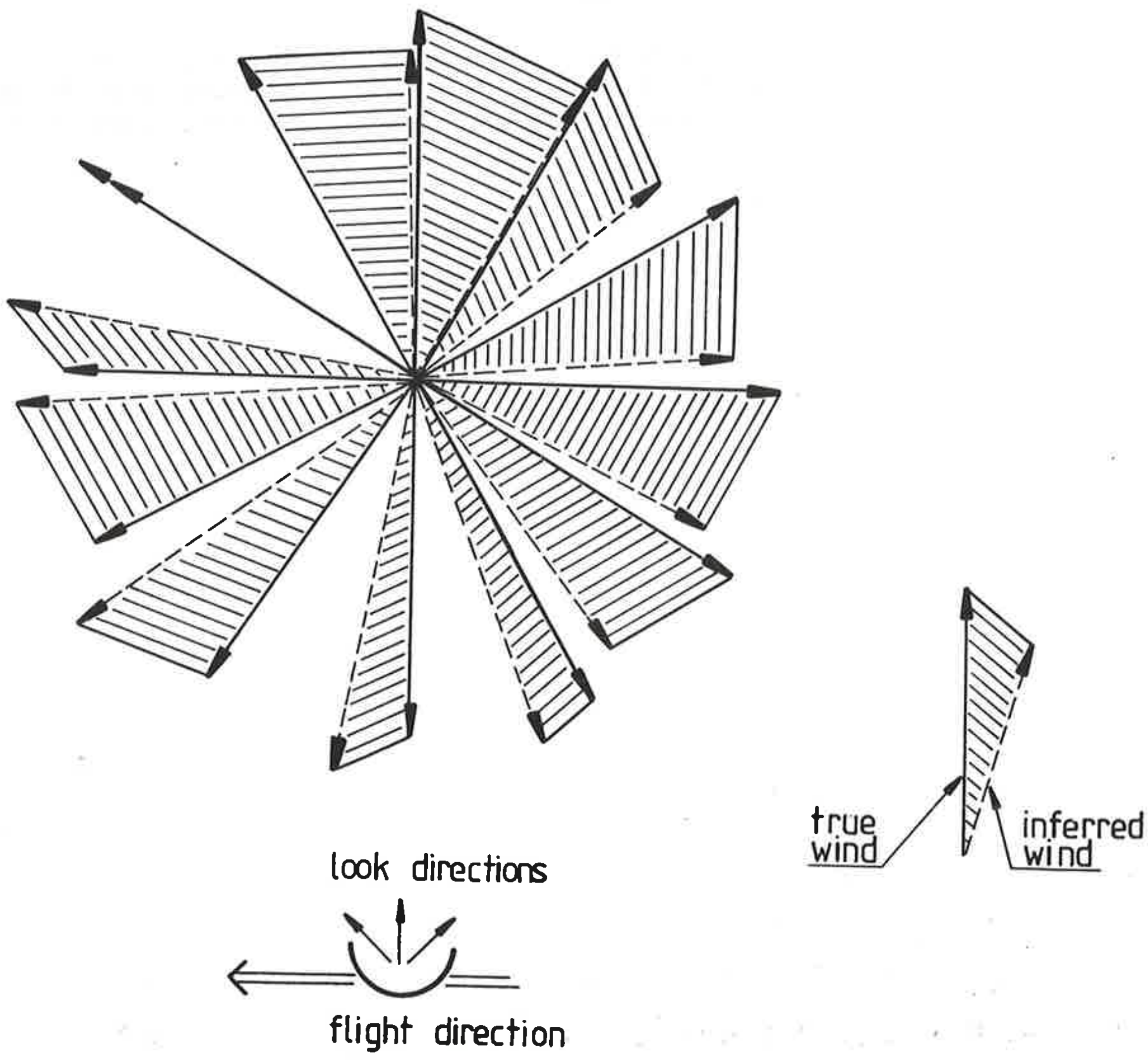

Fig. 5: True winds and wind retrievals from scatterometer model (derived by A. Long, ESTEC) which ignores difference in wind and wave directions for the case shown in Fig. 3.

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