Assessment of scatterometer wind retrieval model by ERS and ADEOS cyclone tracking.

Lidia Saavedra de Miguel
ERS Product Control Service
ERS Mission Coordination and Product Assurance Section
ESA/ESRIN, Via Galileo Galilei, 00044 Frascati, Italy.
tel: +39 6 941 80 679, fax: +39 6 941 80 612
E-mail: Lidia@esrin.esa.it

ABSTRACT

In this paper we study the behaviour of scatterometer instrument in extreme wind conditions. Both ERS and ADEOS data are used.

Selected cyclone events are analysed and results are reported in terms of wind retrieval vector and sigma nought behaviour.

On the one hand, it is observed, in the case of ERS, a good agreement between the expected wind direction and the sensed data. This feature suggests that no saturation is present in sigma nought signals. On the other hand, a poor direction pattern from NSCAT winds is noted. This could be related to the sensitivity of the instrument and/or to the ku-band model used.

An underestimation of the wind speed is clear for both satellites. This fact leads to an assessment of the inversion model with a correction applicable in such extreme conditions.

The correction algorithm is applied for some cyclone events during 1997/1998 and the results are available on the web.

1. INTRODUCTION

The wind stress over the ocean is the main mechanism that force the oceanic circulation at small or large scale. Likewise, the wind field modulates air-sea fluxes of heat, moisture, gases and particles, affecting global and regional climate. It is evident that a good knowledge of wind patterns can improve the weather predictions and minimize the damages produced by severe storms.

Satellite scatterometers are active microwave radar that transmit pulses to the ocean surface. The backscatter power received at the instrument is related to the wind field as it generates the waves than roughen the sea surface. The inversion of the Geophysical Model Function (GMF) is the main way used to extract the wind information from the sigma 0 (backscatter) measurements. Primarily, sigma 0 depends not only on the surface roughness, but also on the incidence angle (which is the angle between the incident radiation and the vertical) and the azimuth (angle between the antenna and the wind direction in the horizontal plane). Parameters as wave height and direction, sea surface temperature, attenuation by rainfall, are normally small and they are neglected when developing a GMF. However, the role of these parameters could become important in events of extreme atmospheric conditions.

The ADEOS Scatterometer (NSCAT) is a ku-band Doppler radar designed to measure backscatter at 25 km resolution, and retrieve wind vectors at 50 km resolution.

The ERS-2 wind scatterometer operates at C band and gets backscatter measurements at about 50 km of resolution sampled on a 25 km grid.

2. DATA SETS

To carry out this study we have used:

- NSCAT Science Products (NSP) Version 4.0. Level 1.7 (Ocean sigma-0’s). Level 2.0 (Wind vectors retrieved using NSCAT-1 model function).
- ERS-2 Fast Delivery Products (FDP) with winds retrieved using CMOD-4 model function.
- Collocated NSCAT/ERS products (WNF produced by IFREMER). The criteria for the co-locations are one hour for time separation and 100 km for spatial separation.

3. WIND FIELD

The great underestimation in the measurements of high wind speeds is one of the problems that must be solved in the scatterometry field. One of the main mechanism that yields to such underestimation is the lack of data at high wind range that does not allow to well calibrate the model. The physical parameters mentioned above and the spatial resolution of the scatterometers contribute to this problem.

The first step we follow in order to correct the wind velocity, is to compare the reports from The Ohio State University Atmospheric Sciences Program Homepage with the scatterometer measurements. Basically, the information given in each report is the radius of the winds at 35 and 50 knots (also 100 knots if the cyclone is very big), the maximum sustained wind (not its position) and the centre location. A depict of some reports is given in Fig. 1

To carry out the simplest correction, that is, add to the scat-

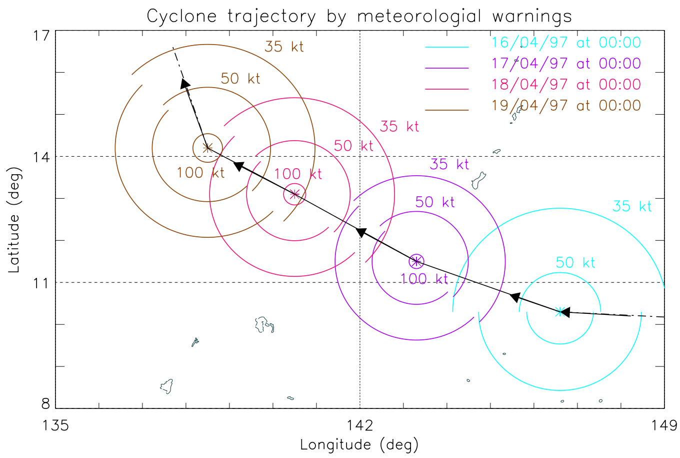


Figure 1: Graphical representation of some reports of The Ohio State University Atmospheric Sciences Program Homepage.

terometer data an amount needed to reach the values given by the reports, we have used 9 cyclones captured with ERS and 30 with NSCAT. The result was a correction very strong for 50 kt and, specially, for 100 kt due to the representativeness error.

3.1 WIND SPEED

3.1.1 REPRESENTATIVENESS ERROR

It is related to the resolution of the scatterometer. It does a 50 km average whereas the report information is taken as a local value. We must see what happens when we have a theoretical model of a cyclone measured with this instrument resolution. The model is a fit of the values of a typical report to a certain function given by:

$$f(r) = a_1 \cdot r \cdot e^{-a_0 \cdot r^{1/2}} + a_2 \qquad (1)$$

The parameters a_0 , a_1 and a_2 are chosen computing a non-linear least squares fit whereas the position of the maximum sustained wind is found minimizing the sum of variances.

Now, we construct a filter that averages the model every 50 kms using a 25 kms grid. As it can be seen in fig. 2, depending on the relative position of the filter we will have different scatterometer patterns in the vicinities of the cyclone centre. Moving the filter grid 2.5 kms across the cyclone, allows us to compute the deviation between the model and the scatterometer profile ten times. An average is perform to obtain the representativeness error shown in fig. 3. The error associated to the filter relative position is also drawn. Each wind speed given in the report, previous to the comparison with the wind scatterometer speed, must be changed by its percentage value that depends on its distance to the cyclone centre. An example of this procedure is plotted in green colour (fig.3).

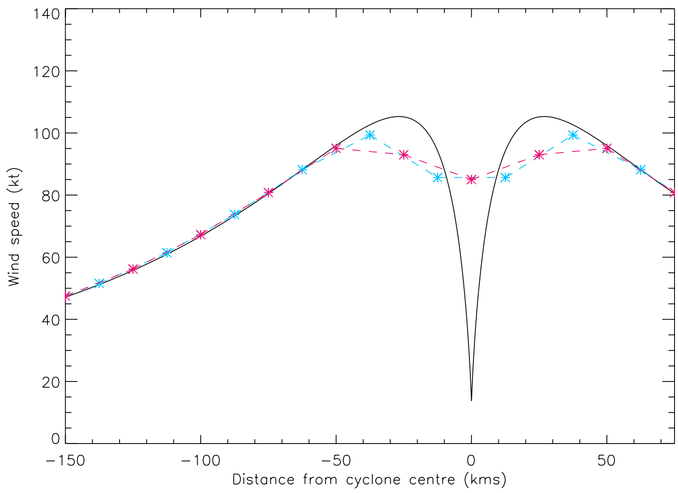


Figure 2: Theoretical model of a cyclone following (1) (black line and two different positions of the filter (red and blue stars).

3.1.2 CORRECTION OF WIND SPEED

The following step is to correct the wind speeds for values greater than 15 m/s. If we depict the bias as a function of the scatterometer wind, it seems that the curve that better fits the data is:

$$F(W_S) \equiv W_R - W_S = b_0 \cdot W_S^{b_1} \qquad (2)$$

where:

F is the scatterometer correction function
W_R is the reported wind
W_S is the scatterometer wind
b_0 and b_1 are parameters that perform the very best fit.

Taking natural logarithm in (2), we can easily perform a linear fit and get the parameters b_0 and b_1. The equation be-

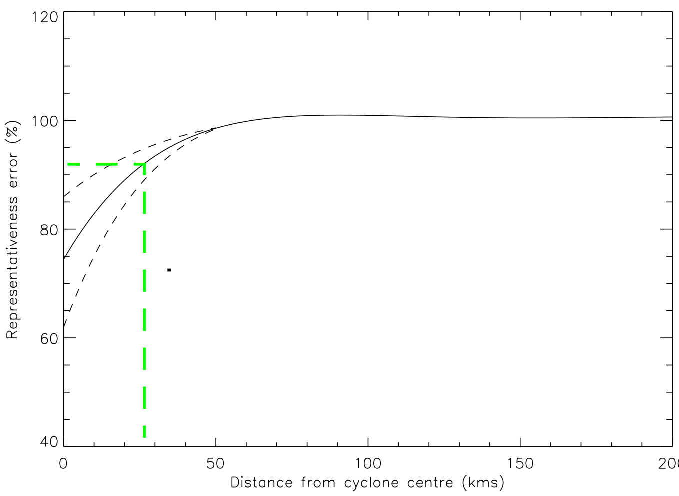


Figure 3: Representativeness error. A reported value must be situated in the graphic and the corresponding percentage value must be used in the collocation with the scatterometer.

comes:

$$\ln(F) = \ln b_o + b_1 \ln W_S$$

The parameters found to fit (3) are:

ERS: $b_0 = 6.79 \times 10^{-6}$

$b_1 = 4.91$

NSCAT: $b_0 = 2.49 \times 10^{-5}$

$b_1 = 4.32$

Fig. 4 and fig.5 are the graphical repr
(2), using the above parameters, for bo
and NSCAT respectively. For the first
more important because the maximum r
s while for the second one, the range i
found retrieved winds up to 30 m/s.

Two examples of wind pattern correc
and 7 for both scatterometers.The resul
shape of the cyclone structure (not per
wind speed much nearer to the real one.

3.2 WIND DIRECTION

Until now, we were talking about the
locity but the wind direction is a feature t
are also capable to retrieve. If we observe
of a strong event, it is easy to see that the
allow to distinguish the centre of the cy
Scatterometer localize it with a good prec
the wind grows in intensity the NSCAT lo
the direction. This is clearly shown in fi
events of increasing strength. In fig. 8.a
speed is 55 kt and the scatterometer cap
good. Fig 8.b shows a structure with a cen
ficult to fix (maximum winds of 95 kt) w
sition of the centre becomes nearly imp
(125 kt of maximum wind speeds).

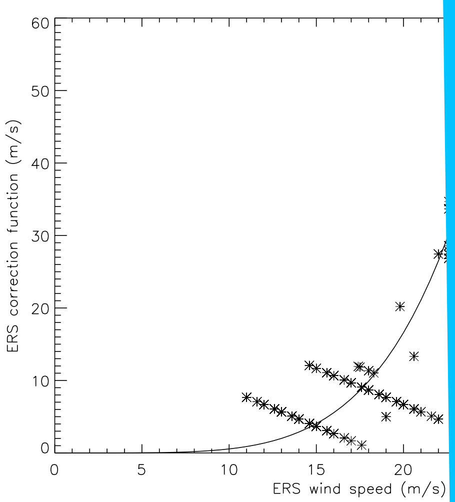
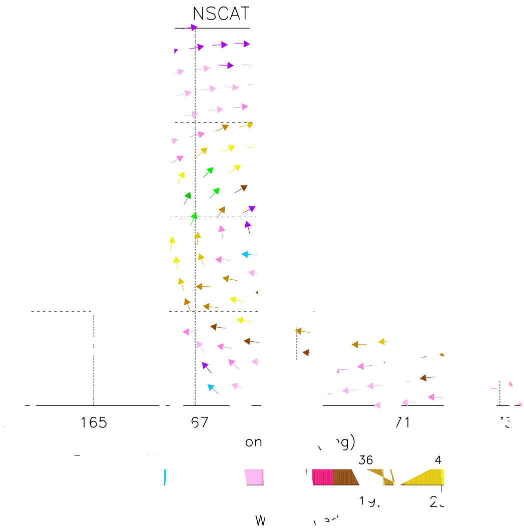


Figure 4: Correction model for ERS Scatte



.a: Cyclone YALI, 22nd March, 1998. Maximum sus-
winds of 55 kt.

ne ISA, 16th A

Figure 9.b: Cycl
winds of 95

4. CARACTERISATION OF σ^o AT HIGH WINDS

4.1 σ^o PROFILES

In order to find the reason for this difference in direction pattern, we have analysed the sigma_0. In normal weather conditions, the NSCAT sigma_0 are 1.5-2 db greater than ERS-2 sigma_0 (fig. 10.a & fig. 11.a). This feature could be related to the different bands of the radiated signal, C-band for ERS-2 (5.3 Ghz) and Ku-band (14 Ghz) for ADEOS Satellite. Because of that, the retrieved winds of NSCAT are 1-1.5 greater than those of ERS-2 SCATT.

In extreme weather conditions, the signals of both scatterometers are quite similar; NSCAT signal does not grow as much as the ERS-2 SCATT signal does (fig. 10.b & fig. 11.b). This could mean that the NSCAT is less sensitive in these conditions, probably because the rain attenuation is more important in Ku band.

To cast light on this point, it would be interesting to go deeply into the fore and aft signal behaviours. If the phenomenon of saturation is present, the fore and aft antennae are supposed to measure the same signal and the direction information, related to their difference, would be lost. The ERS-2 SCATT, based on fig. 9, do not show a saturation behaviour while the NSCAT leads us to think that there is a possible saturation or a poor performance of the model.

4.2 FORE-AFT DEVIATION

The maps of fore minus aft differences can help us to better understand the influence of sigma_0 behaviour on the wind direction patterns.

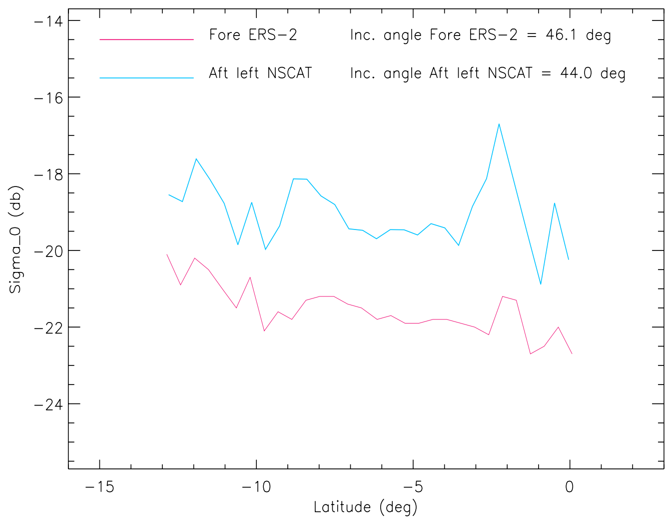


Figure 10.a: Sigma_0 along the swath for both scatterometers in calm weather conditions.

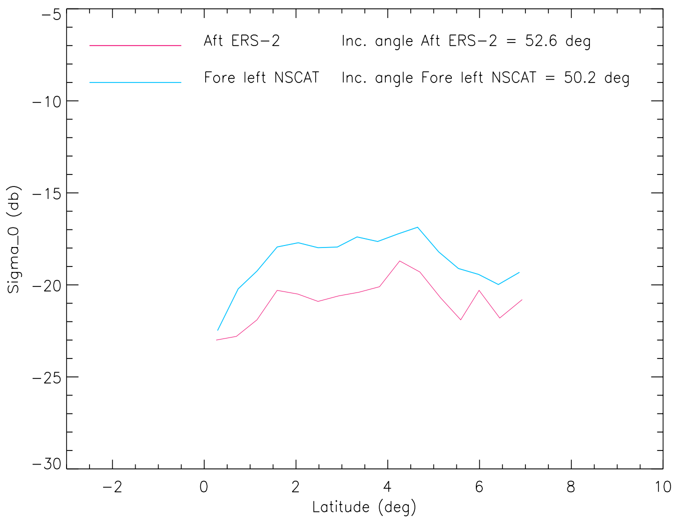


Figure 11.a: Sigma_0 along the swath for both scatterometers in calm weather conditions.

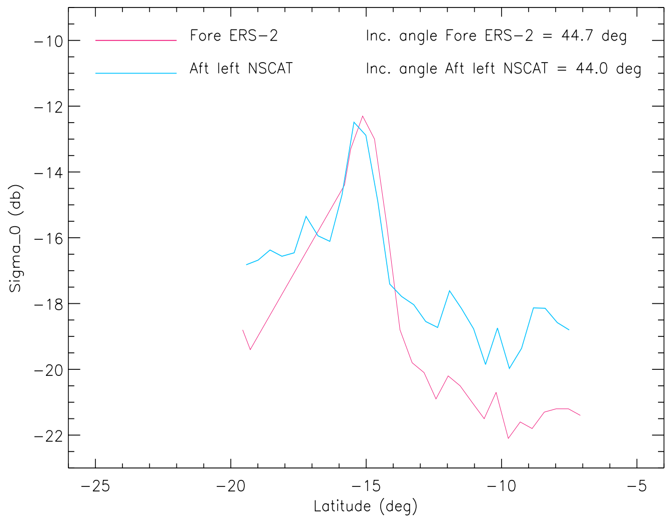


Figure 10.b: Sigma_0 along track DRENA cyclone, 9th January, 1997.

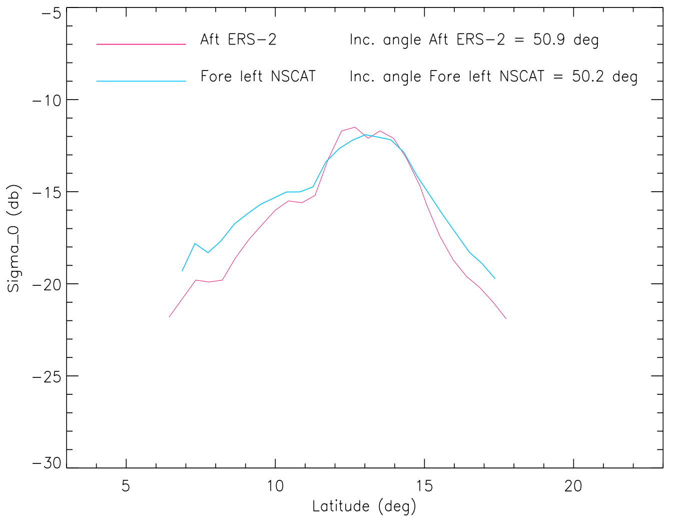


Figure 11.b: Sigma_0 along track ISA cyclone, 18th April, 1997.

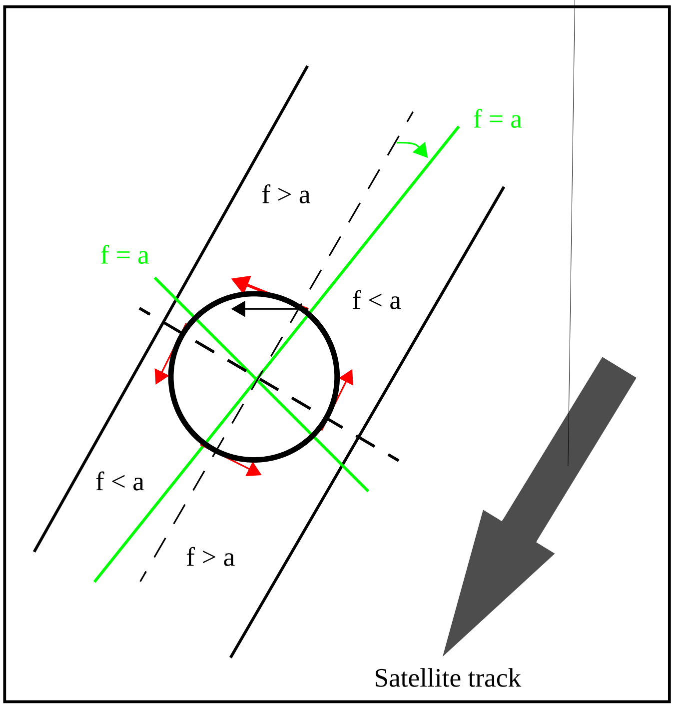


Figure 12: Diagram of fore - aft values.

What we expect to obtain is represented in fig. 12 for a cyclone with the wind blowing anti-clockwise (North Hemisphere) and a descending pass of the satellite. If the wind were tangential to the circle (red arrows), the dashed lines should represent the zone where the fore and aft antennae have the same value. As the wind is rotated 15-20 degrees (black arrow), the lines are tilted by the same angle (green lines). The zones of fore signal greater or less than aft signal depend on the upwind, downwind or crosswind direction respect to the two beams. Table 1 shows the possible combinations for the above geometry.

In fig. 13 we have evaluated the difference f-a in the cyclone ISA captured by ERS-2 on 18th of April, 1997 (115 kt of maximum sustained wind). It can be seen the structure that will allow a good wind direction retrieval. However, fig. 14 (corresponding to the cyclone of fig. 8.c) does not show the same good results. The difference is clearly seen in fig. 15, where the plots are done using two colours: red for f-a > 0 and blue for f-a < 0. ERS-2 SCATT reproduce precisely the expected results given in fig. 12 whereas it is evident, for NSCAT, a deficiency of its sensitivity when measuring this kind of atmospheric events.

Table 1: Wind direction with respect to the antennae fore and aft and their relative measurements for the geometry of fig. 12.

	fore	**aft**
f > a	upwind	crosswind
f > a	downwind	crosswind
f < a	crosswind	upwind
f < a	crosswind	downwind

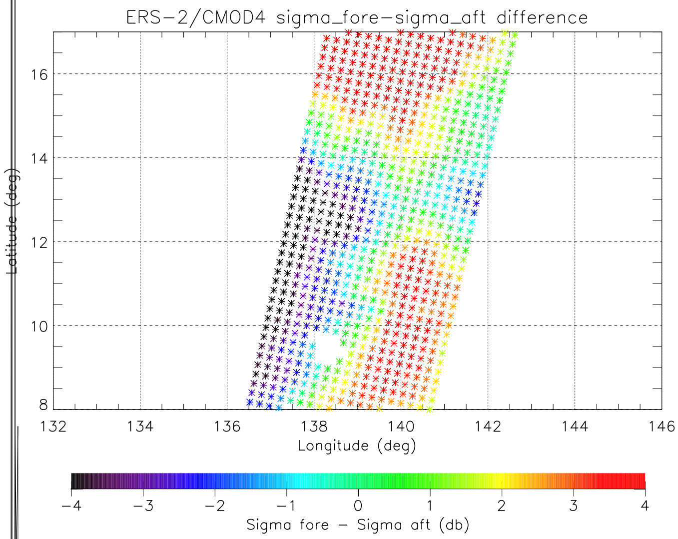


Figure 13: Graphical deviation fore minus aft ERS data for the cyclone ISA on 18th of April, 1997.

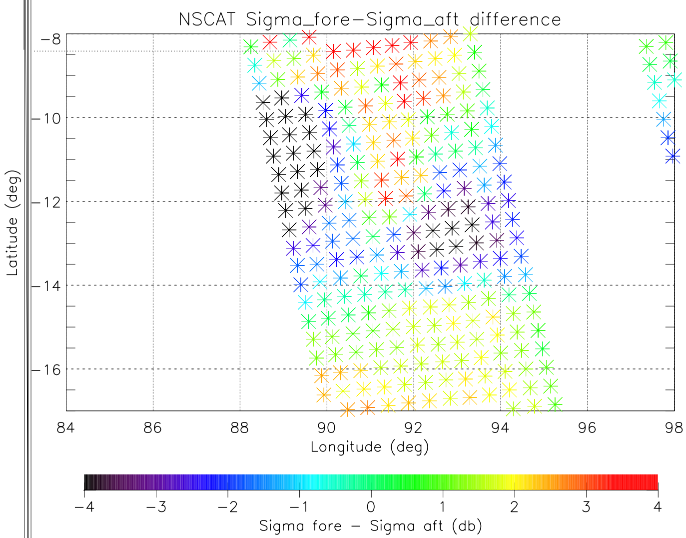


Figure 14: Graphical deviation fore minus aft NSCAT data for the cyclone PANCHO on 22nd of January, 1997.

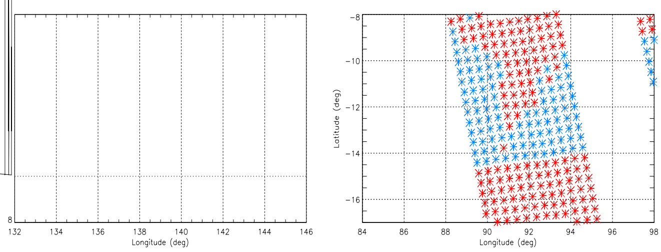


Figure 15: Same as fig. 13 (left one) and fig. 14 (right one) using two colours, red for f-a > 0 and blue for f-a < 0.

5. CONCLUSIONS

Both scatterometers far and away underestimate the wind speeds when measuring atmospheric phenomena with strong wind fields associated. However, a supposed better calibration of NSCAT allows to obtain wind values up to 30 m/s while ERS-2 SCATT has its limit at 23 m/s. In order to correct the underestimation drawback, a preliminary model that improve the quality of high scatterometer wind speeds have been developed taking into account the effect of the instrument resolution.

The problem of the large amount of data needed to calibrate the model (mainly above 50 kt) is not solved and future data acquisition will help us to construct a more suitable data set.

A good capability of ERS-2 SCATT to measure wind direction has been observed and, because of that, it seems that no saturation is present in sigma_0 signal. An expected behaviour of sigma fore minus sigma aft deviation confirm this point.

Quite the contrary, the NSCAT presents a poor direction pattern. The study of sigma_0 is needed in order to check the sensibility of the instrument. The Ku-band model could also influence the observed direction winds.

In normal weather conditions NSCAT usually measures 1.5-2.0 db more than ERS-2 SCATT yielding to a wind retrieval slightly superior (about 1-1.5 m/s). As the wind increases its strength, the signals become similar. This suggests a lost of sensitivity of NSCAT, fact that is also pointed out by the behaviour of sigma fore minus sigma aft difference. Precipitation attenuation could be the main mechanism responsible for the irregular behaviour of sigma_0.

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