Tracking of tropical cyclones with the ERS Scatterometer

***P. Lecomte, **R. Crapolicchio, *J. Gallego,**L. Saavedra**

***ERS Mission Coordination and Product Assurance Section**
ESA-ESRIN APP-AEM via Galileo Galilei 00044 Frascati Italy

**** Serco srl Via L. Manara 5 00044 Frascalti, Italy**

tel: ++39 06 941 80 670, fax: ++39 06 941 80 612
E-mail: plecomte@esrin.esa.it, rcrapoli@esrin.esa.it, jgomez@esrin.esa.it,lidia@esrin.esa.it

Abstract - **Every year Tropical Cyclones (TC) produce important damages on a high number of countries: the floods caused for the heavy rain, strong winds and bad sea conditions produce human and economic losses. Satellite data can help the scientific comunity to study this events. In particular the processing of the backscattering measurements acquired over the wind field at sea level. The knowledge of the wind field structure for the TC can help the scientific community to better understand and forecast these events. To meet the needs of the scientific community The Product Control Service (PCS) at ESRIN has developed a post-processing procedure for the fast delivery (FD) data acquired with the C-band Scatterometer (Scat) flew onboard the ERS satellites. The major skills of this post-processing are: the detection of TC, a quality improvement of the retrieved wind field and the availability on a web in near "real-time"of data and reports about TC.**

INTRODUCTION

The ERS Scatterometer is a three antennae radar working at C-band. This frequency es very sensitive to the sea surface roughness that, by using an appropriate model, could be related with the wind field. The returned echoes are stored on satellite and downloaded to the ground station every one-orbit time (100 minutes). On the ground station the backscattering coefficients (three sigma naught for three different azimuth angles) are retrieved from the echoes with a resolution of 50x50 kilometers and re-sample with a grid of 25x25 kilometers. In addition, by using a wind retrieval model (the operational one is the CMOD-4 [1]) and an ambiguity removal algorithm, the wind vector (speed and direction) is computed from each sigma naught triplet. Within three hours from sensing sigma naught measures and wind field estimation are provided to international meteorological and oceanographic organizations via the GTS of the World Meteorological Organization. The European Centre for Medium-Range Weather Forecasts (ECMWF) has proved that the assimilation of Scat data into meteorological model can improve the forecast and the estimation of the position of the TC [2].

However, wind information given in the FD data acquired over a TC shows two major problems. The first one is in the retrieved wind speed that is very far from the real wind speed and the second is the ambiguity removal (sometimes the Scat wind direction is not the correct one). These two problems are linked to the calibration of the CMOD-4, that was not tuned for high wind speed (as we have in the TC), and with the performance of the ambiguity removal algorithm used at present in the ground processing.

In this paper is described a procedure used within the ESRIN PCS to detect the TC from Scat FD data and to upgrade the wind field. In the conclusion it is given a description of the report information available on the web.

THE DETECTION OF A TC

The Vortex Integral.

The first step is the detection of the TC using the criteria of the high vorticity of a node. The vorticity of one node is calculated using the following formula:

$$I_{VORT} = \frac{\sum_{j=1}^{n-2}[V_J(n-1,j) - V_J(0,j)] + \sum_{i=1}^{n-2}[V_I(i,n-1) - V_I(i,0)]}{\sum_{i=1}^{n-2}[V(i,0) - V(i,n-1)] + \sum_{j=1}^{n-2}[V(0,j) - V(n-1,j)]}$$

with:

$$V_I(i,j) = V(i,j)\cos(\phi_M(i,j) - \phi(i,j))$$

$$V_J(i,j) = V(i,j)\sin(\phi_M(i,j) - \phi(i,j))$$

V is the wind speed

ϕ is the wind direction wrt North

ϕ_M is the mid beam look angle

Figure 1 shows the nodes used (red points) in the case of n = 7. For the nodes at near and far range of the swath, it is done

```
X X X X X X X
X X X X X X X
X X X X X X X
X X X X X X X
X X X X X X X
X X X X X X X
X X X X X X X
```

Figure 1: Red points (nodes) are used to calculate the vorticity of the green node.

a reconstruction of the set substituting the missing points by the one situated in the opposite part of the set, as a specular image of the existing points, but adding 180 degrees to the given direction. This addition is performed in order to have reconstructed nodes with a consistent turn of the wind with respect to the original set. The criteria of selection is that the vorticity of a node is greater than 0.75 or less than -0.75. If the vorticity is not very high but the wind speed is greater than 19.7 m/s for that node, the selection is also done. The 79.5% of the events related to the TC hit by a Scatterometer pass are detected by this procedure.

The Centre estimation of a TC.

Once a product is selected, the second step is the estimation of the TC centre. The centre estimation procedure uses the properties of the fore and aft antennae signals as described in [3] and [4]. The method uses a linear fit for two perpendicular lines where the difference of sigma nought fore and aft is zero. The lines are tilted 10 degrees with respect to the satellite swath and they should cross the eye of the cyclone. If the distance between the high vorticity node (h_vort) and the cross point (c_ point) defined by the intersection of the two line fits is greater than roughly 300 kms, the event is rejected and checked manually afterwards. If that is not the case, the procedure searchs for the TC centre moving the c_point towards the h_vort. This action is repeated until the distance between the two points is less than 50 kms (the scat data resolution). The centre of the TC is the c_point if the number of iteraction is greater or equal than two and the h_vort if the contrary.

THE REFINED WIND FIELD

The Wind Direction Correction

At this stage, we compare the wind direction in the FD data with a theoretical model for a TC. A new ambiguity removal procedure is performed taking into account that the wind blows with an anticlockwise turn for the Northern Hemisphere or clockwise turn for Southern Hemisphere. Given a centre, the theoretical direction of the wind for a node is the tangent in that node to a circumference centred in the TC centre and rotated 10 degrees as shown in fig. 2.

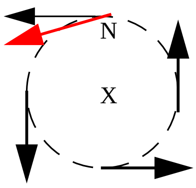

Figure 2: the red arrow represents the theoretical turn of the wind in that node 'N 'for a cyclone centred in 'X'.

If the difference between the wind in FD data and the theoretical model is greater than 60 degrees, a new direction is searched among the four solutions of the wind retrieval function. It will be selected the direction with minimum difference with respect to the theoretical one. If this minimum difference is less than 60 degrees, then the new direction is chosen; if not, no change is done.

The Wind Speed Correction

A model that takes into account the slight calibration of CMOD-4 for high wind speeds and the error related to the resolution of the instrument is used to correct the wind speeds. The method is fully explained in [4]. Winds higher than 15 m/s are corrected with a result of a more realistic pattern of wind field structure and speeds.

CONCLUSION

The Product Control Service (PCS) at ESRIN has developed a post-processing for the ERS SCAT data acquired over a TC in order to improve the quality of the wind field. Moreover, the PCS gives to the scientific community a quasi real-time report for each TC event sensed by ERS Scat with the following contents:

- a backscattering image of the TC with the superposition of wind field. The backscattering image is obtained by the modulation of the three color components (Red, Green Blue) with the signals coming from the three scat antennae after a spatial re-sampling and normalization with an empirical model of the sea backscattering to avoid the effect of the incidence angle.
- a table with the centre position and the maximum wind speed of the TC.
- a 2 dimensional plot with the structure of the TC
- the FD data with the re-processed wind field
- an ASCII file with the geolocated wind field data.

An example of the backscattering image before and after the re-processing of wind field is shown in fig. 3 and 4 respectively in the case of TC DAVINA. Figure 5 shows the structure over the same TC acquired few days before. Table 1 and table 2 show a comparison between the information derived from Scat data and the warning issued by meteorological centres in the case of TC DAVINA and HALI. For the first cyclone the Scat data confirm the warning position centre while for the second case, Scat data give the opportunity to have a more precise localization of TC centre with respect to meteorological warnings. It is important to underline the singleness of this report. All the information given in the report is retrieved using only the Scat data within few hours from sensing. The full reports concerned the last TC events as well as the Scat data are available from the web site http://www.pcswww.esrin.esa.it.

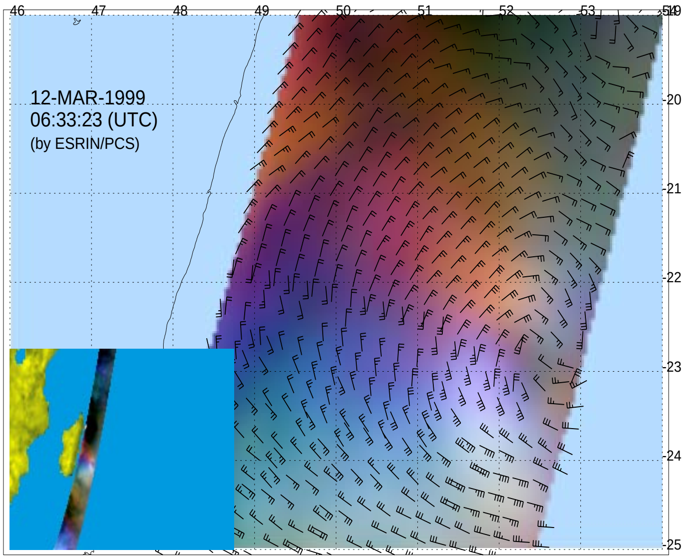

Figure 3: Scat image of Davina.

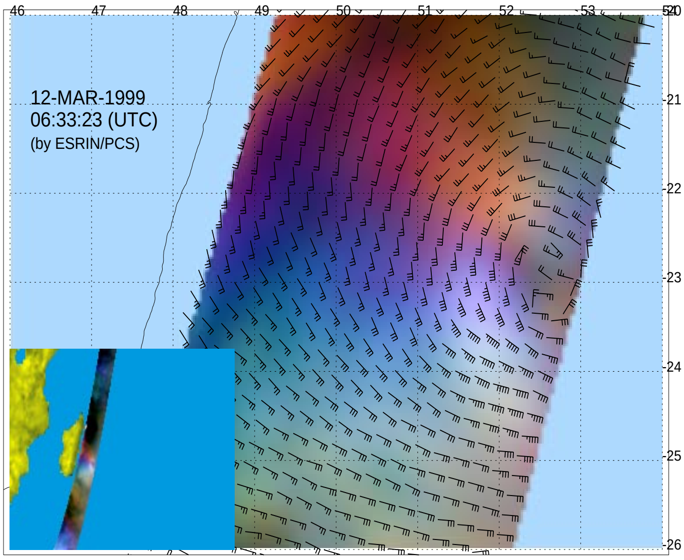

Figure 4: Re-processed image of Davina.

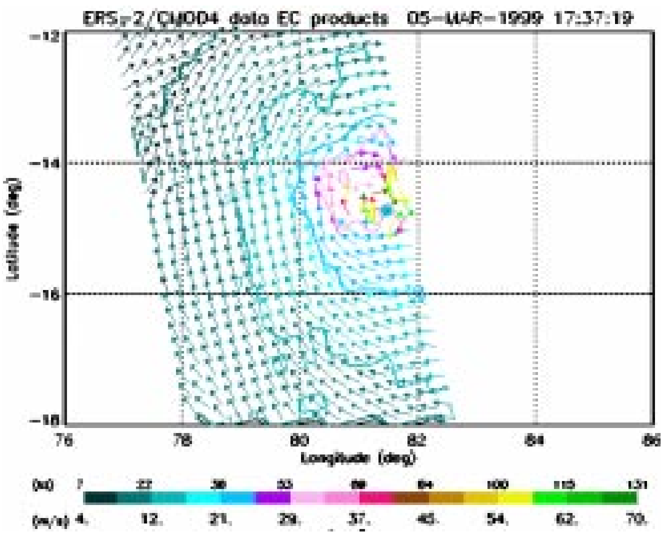

Figure 5: Structure of Davina on 5th March, 1999.

Table 1: TC DAVINA (SW Indian)

12/03/1999	ERS2-SCATT (after re-proc.)	METEO WARNING
time	06:33:23	06:00:00
latitude centre (deg)	-22.9	-23.0
longitude centre (deg)	52.2	52.3
max. wind speed (kts)	56.25	60

Table 2: TC HALI (SW Pacific)

16/03/1999	ERS2-SCATT (after re-proc.)	METEO WARNING
time	10:06:10	12:00:00
latitude centre (deg)	-22.0	-24.8
longitude centre (deg)	195.4	197.5
max. wind speed (kts)	35.6	45

REFERENCES

[1] P. Lecomte, ‘CMOD-4 Model Description’, ESA technical note, issue 1.2, March 1993.

[2] D. LeMeur, L. Isaksen, B.Hansen, R. Saunders and P. Janssen, Global Validation of ERS Wind and Wave Products, January 1998, ESA contract No. 8488/95/NL/CN.

[3] P. Lecomte, L. Saavedra, ‘Comparison of ERS and NSCAT Scatterometer for Ocean Applications Under very high Wind Conditions’, Proceedings of IGARSS’98.

[4] L. Saavedra, ‘Assessment of Scatterometer wind retrieval model by ERS and ADEOS Cyclone Tracking’ Proceedings of Emerging Scatterometer Applications - from Research to Operations, 5-7 October 1998, ESTEC, The Netherlands ESA SP-424, pp. 221-227, November 1998.