esa esrin	**ERS-2**	Doc. No. : ER-SA-ESA-SY-1121 Issue : 1.0 Date : 2/26/93

Wind Scatterometer Processing Requirements From σ° triplets to dealiased wind

Pascal LECOMTE
ESRIN DPE/OM

Created February 26, 1993

esa esrin	ERS-2	Doc. No. : ER-SA-ESA-SY-1121 Issue : 1.0 Date : 2/26/93

Wind Scatterometer Processing Requirements From σ° triplets to dealiased wind

Pascal LECOMTE
ESRIN DPE/OM

Created February 26, 1993

Table of Content

Change Record

Issue	Date	Pages	Description of change
0.0	2/19/93	all	Draft issue
1.0	2/26/93	all	First issue

1 : Scope

This document defines the ground processing algorithms for the ERS-1 AMI wind mode (Scatterometer) from the σ° triplets to the wind speed and direction, including the wind retrieval and the ambiguity removal processing.

In the current (Norsk Data/FPS) LRDPF, these functions are performed by customer furnished code. This specification is intended as the basis for an industrial-strength implementation of the same algorithms.

The input and output interfaces are covered to the level of detail necessary for a clear description of the processing stages themselves. A detailed description of the output format of the chain is given in A-1.

This document only specifies the mathematical form of the algorithms. This does not prejudice the final software structure, which has to be optimised with respect to the target hardware configuration and existing runtime requirements given in A-4.

† To further clarify particular points details of the current implementation are provided as an example and marked "†". These remarks are not to be regarded as constrains on the implementation. The specific values used are often dictated by current performance constrains.

† A description of the current implementation is given in annex C.

• The notes referring to vocabulary and warnings will be indicated with a "•".

2 : Documentation

2.1 : Applicable documents

A-1	ER-IS-EPO-GS-0201	ERS-1 Ground Stations Products Specification
A-2	ER-TN-EPO-GP-1120	Cmod4 model Description
A-3	ER-RS-MDA-SY-0005	Fast Delivery Processing Chain, Low Rate Data Processing Facility Requirement Specification

2.2 : Reference documents

R-1	ER-SP-DSF-SY-0006	Wind Scatterometer Ground Processing Requirements up to σ° triplets
R-2	ER-TN-EPO-JP-0016	Cmod3 model Description
R-3	ER-TN-ESA-GS-0004	Wind extraction and Ambiguity Removal Interface and Installation guide.
R-4	ER-RP-ESA-GS-0028	Study of a Method to De-Alias Winds from ERS-1 Data.

3 : Overall Scatterometer Description

An overall description of the measurements principle (including the geometry), the on-board instruments, the instrument Time-lining and the ground processing description up to the $\sigma°$ triplets is given in R-1.

4 : Wind Processing Description

The processing of the wind vector from the $\sigma°$ triplets is made in two major stages, the wind retrieval and the ambiguity removal.

The wind retrieval is performed at node level and uses only the information available at that level. Its output is up to four wind vector solutions (wind speed and direction) for each node. To each of these solutions is attached a parameter describing the distance between the $\sigma°$ triplets measurements and the solution. The computation is based on an analytical model function for the conversion of $\sigma°$ measurements to the wind speed and direction for a given geometry (incidence angle).

Two versions of the algorithm can be defined as a result of a trade-off between precision and CPU time. The Precision algorithm uses an analytical description of the model function and re-computes each time the $\sigma°$ for a given wind vector. The fast method uses a table containing the $\sigma°$ value for each wind speed, wind direction and incidence angle (called herein “model table”); the precision is limited by the size of the table.

† In the current LRDPF, both algorithms are coded. The fast version is used operationally. The precision version is 10 times slower than the fast version.

The two algorithms will be described separately hereafter.

The Ambiguity removal is performed at product level, i.e. the choice of best solution for each node, from up to four available, is constrained to be consistent with solutions chosen for adjacent nodes.

5 : Fast Wind Retrieval

5.1 : General Description

The wind retrieval computes the principal minima of the distance between the measured $\sigma°$ triplets and the model.

The model defines the relationship between $\sigma°$ measured and wind speed, wind direction and incidence angle, $\sigma° = f(V, \varphi, \theta)$. The model currently used is described in A-2. It is assumed that the incidence angle is precisely known, therefore the minimisation is only done with respect to the wind speed and direction.

- The first stage consists of computing the local minima of Euclidean distance with respect to the wind speed and wind direction.

  † The current implementation computes the wind speed which gives the minimum Euclidean distance at constant wind direction. This is performed every 10° for the wind direction. The results of this stage is a table of 36 minimum Euclidean distances and the corresponding wind speed.

- Extract the first four minima. The output of this second stage is up to four solutions (wind speed, wind direction and Euclidean distance).

  † Depending on the wind direction with respect to the scatterometer, the total number of minima is between 2 and 6. Experience shows that only the four smallest distances can only be solution of the problem.

- The third stage of the process is to rank the solutions by increasing Euclidean distances. The rank 1 solution has the smallest Euclidean distance.

- In the general case, the definition of the distances required as solution is not the Euclidean distance. In particular here, the ambiguity removal uses a maximum likelihood definition of the distance. Therefore the maximum likelihood distance shall be computed for the four solutions, the ranking remaining the same (refer to Annex B).

At least two solutions shall be computed by the fast wind retrieval algorithm. When only one solution is found (usually because the second has a wind speed outside the table), no solution is given in output.

5.2 : Functional Block Diagram

A Fast Wind Processing functional block diagram is shown in Figure 5.2.a. It contains the major processing stages as well as the external interfaces. Each block element as well as the interfaces will be addressed in the following sections.

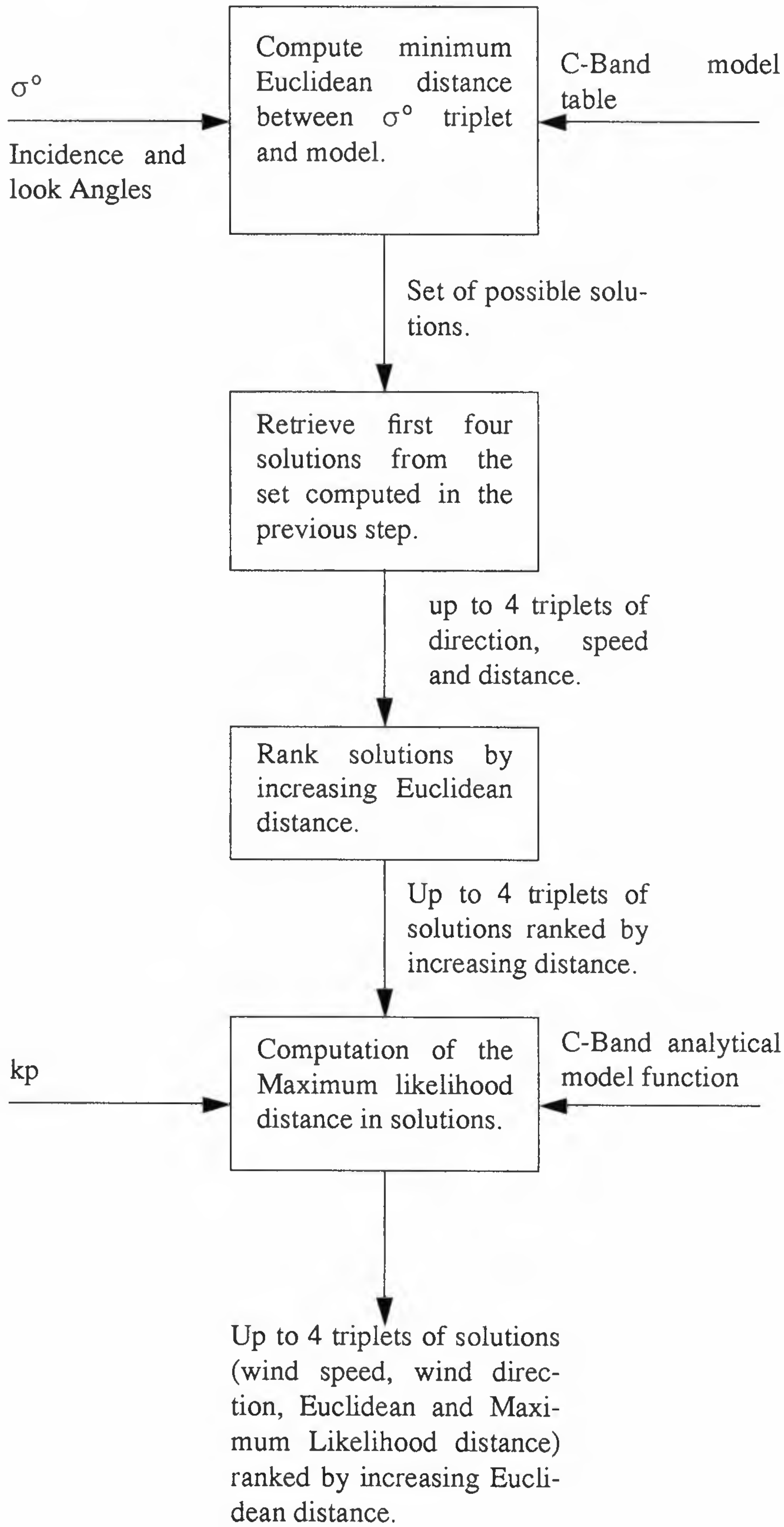

Figure 5.2.a : Fast Wind Processing functional block diagram.

5.3 : Input Parameters

The input parameters entering the Wind retrieval processing are categorised as:

- Data delivered by the raw data up to σ° triplets processing,
- Model dependant inputs,
- Externally provided data.

The Data delivered by the raw data up to σ° triplets processing comprises as shown by the block diagram:

- σ° triplets,
- kp triplets,
- node incidence (one per beam).
- look angle (one per beam),
- annotation qualifying σ° triplets computation:
  = Measurement validity,
  = arcing flag,
  = Land flag,
  = ice flag.

The definitions of angles (look angle, incidence angle, wind direction) are given in annex A.

The model dependant inputs comprises:

- C-Band model table, implementation specific,
- C-Band analytical model function.

† The current C-Band model table has the following characteristics:
  - θ varies from 18° to 42° with a step of 1°, i..e. 55 values,
  - φ varies from 0° to 180° with a step of 5°, i..e. 37 values,
  - V varies from 0.5 m/s to 60.0 m/s with a step of 0.5 m/s, i..e. 120 values.

  The size of the table is 244200 grid points coded on 4 bytes, and the total size is 976800 bytes.

• It is recommended that the model table is created and/or tested against the analytical model function at run time.

External Data are those data required for processing, which are not contained in the output of the raw data up to σ° triplets processing.
This data comprises of:

- control parameters:
  = model table size and steps,
  = precision required for wind speed and direction,
  = implementation specific input parameters.

All external data may be updated, if the need arises.

5.4 : Output Parameters

The output data of the Wind retrieval processing are:

- wind solutions, speed and direction (up to four solutions),
- maximum likelihood distance for each solution,
- Euclidean distance for each solution,
- annotations qualifying the processing performed:
  = number of solutions,
  = no valid solution computed.
  = implementation specific output parameters.

5.5 : Fast Wind Processing functions

5.5.1 : Minimisation

The computation of the minimum of the Euclidean distance between the measured σ° triplet and the model is performed

The definition of the Euclidean distance is as follows:

$$M^2 = \sum_{i=1}^{3} (\hat{\sigma}_i - \tilde{\sigma}_i)^2$$

where:

M is the Euclidean distance
i is the antenna index (1: Fore beam, 2: Mid beam, 3: Aft beam).
$\hat{\sigma}$ is the measured σ° values for the beam i
$\tilde{\sigma}$ is the σ° values read from the table for the beam i

The following points have to be noted:

- In the model used to create the table, the definition of the wind direction is the azimuth of the point from where the wind is blowing with respect to beam axis,
- Each antenna has a different incidence angle
- Each antenna has a different look angle with respect to the wind direction. The deviation between two antennae beam (Fore-Mid or Mid-Aft) is approximately 45°.

• Geometrical details are given in annex 1.

† In the current implementation, the minimisation is performed at constant wind direction, using a Turning point analysis applied on the elements of the model table.For each wind direction from 0° to 360° with a step of 5°, the wind speed which gives the minimum Euclidean distance is computed. It is assumed that only one minimum exist at a given wind direction. In order to optimise the number of computations, the first minimisation (at 0°) starts with a wind speed of 8 m/s (mean wind speed). The other minimisations (at 5°, 10°, ..., 155°) start at the wind speed, which correspond to the minimum Euclidean distance computed during the previous minimisation.

The result is a table of elements containing the wind speed and wind direction solutions together with the associated Euclidean distance for all the local minima found.

5.5.2 : Retrieval of the first four minima

This function consists in computing the local minima of the Euclidean distance with respect to the wind direction.

† This selection gives nominally up to four solutions. There is no demonstration proving this assumption. The experience shows that the number of minima never exceeds ten. The statistics shows that the correct solution of the wind is always within the four first minima selected (i.e.: the four lowest values), therefore, the result of this stage is limited to the first four minima.

The results of this stage is a table of 4 rows and 3 columns, each row contains the parameters of one minimum, the columns corresponding to the speed, the direction and the Euclidean distance. If less than four minima are found, the remaining rows are filled with zeroes.

5.5.3 : Ranking of the minima

The up to four minima are ranked (sorted) by increasing value of the Euclidean distance. The first row contains the information (speed, direction, distance) of the lowest Euclidean distance. If less than four solutions are given, the remaining rows are filled with zeroes.

5.5.4 : Computation of the maximum likelihood Distance

The distance definition used in the Ambiguity removal part of the algorithm is not the Euclidean distance but the Maximum Likelihood Distance.

This parameter characterises the probability of obtaining the measured σ° triplet given that the true σ° triplet is on the model surface, assuming a Gaussian probability law.

The definition of the maximum likelihood distance is as follows:

$$\mathcal{R} = \sum_{i=1}^{3} \left(\frac{\hat{\sigma}_i - \tilde{\sigma}_i}{kp_i \cdot \tilde{\sigma}_i} \right)^2$$

where:

- $\mathcal{R}$ is the maximum likelihood distance
- i is the antenna index (1: Fore beam, 2: Mid beam, 3: Aft beam).
- $\hat{\sigma}$ is the measured σ° value for the beam i
- $\tilde{\sigma}$ is the σ° value computed with the analytical model function for the beam i
- kp is the noise characteristics measured for the beam i

The results of this stage is a table of 4 rows and 4 columns, each row contains the parameters of one minimum, the columns corresponding to the speed, the direction, the maximum likelihood distance and the Euclidean distance. If less than four minima are found, the remaining rows are filled with zeroes.

6 : Precision Wind Retrieval

6.1 : General Description

The principles are identical to the one described in chapter 5. The purpose of the precision processing is to increase the precision of the results (wind speed and wind direction) in a such way that the noise in the result is only related to the precision of the instrument and not to the precision of the algorithm (limited by the table discretisation).

In order to reduce the numerical noise the results shall be given at least with a precision of 1° for the wind direction and 0.1 m/s for the wind speed (see Annex D).

The algorithm starts from the 4 solutions coming out of the fast wind retrieval algorithm, and uses a Newton-Raphson technique to derive minima. In contrast to the Fast wind retrieval, σ° are computed using the analytical model function.

† This is applied every 1° around each of the four solutions (5°), and the computation is stopped when two successive results in wind speed have a deviation smaller than 0.1 m/s

The minimisation is made using the Euclidean distances. The solutions are re-sorted and the Maximum Likelihood distances are computed.

The solutions found substitute the one derived from the Fast wind retrieval.

As for the fast wind retrieval algorithm, at least two solutions shall be computed by the precision wind retrieval algorithm. When only one solution is found, no solution is given in output.

6.2 : Functional Block Diagram

A Precision Wind Processing functional block diagram is shown in Figure 6.2.a. It contains the major processing stages as well as the external interfaces. Each block element as well as the interfaces will be addressed in the following sections.

6.3 : Input Parameters

The input parameters entering the Precision wind retrieval processing are categorised as:

- Data delivered by the raw data up to σ° triplets processing,
- Output from the Fast wind retrieval,
- Model dependant inputs,
- Externally provided data.

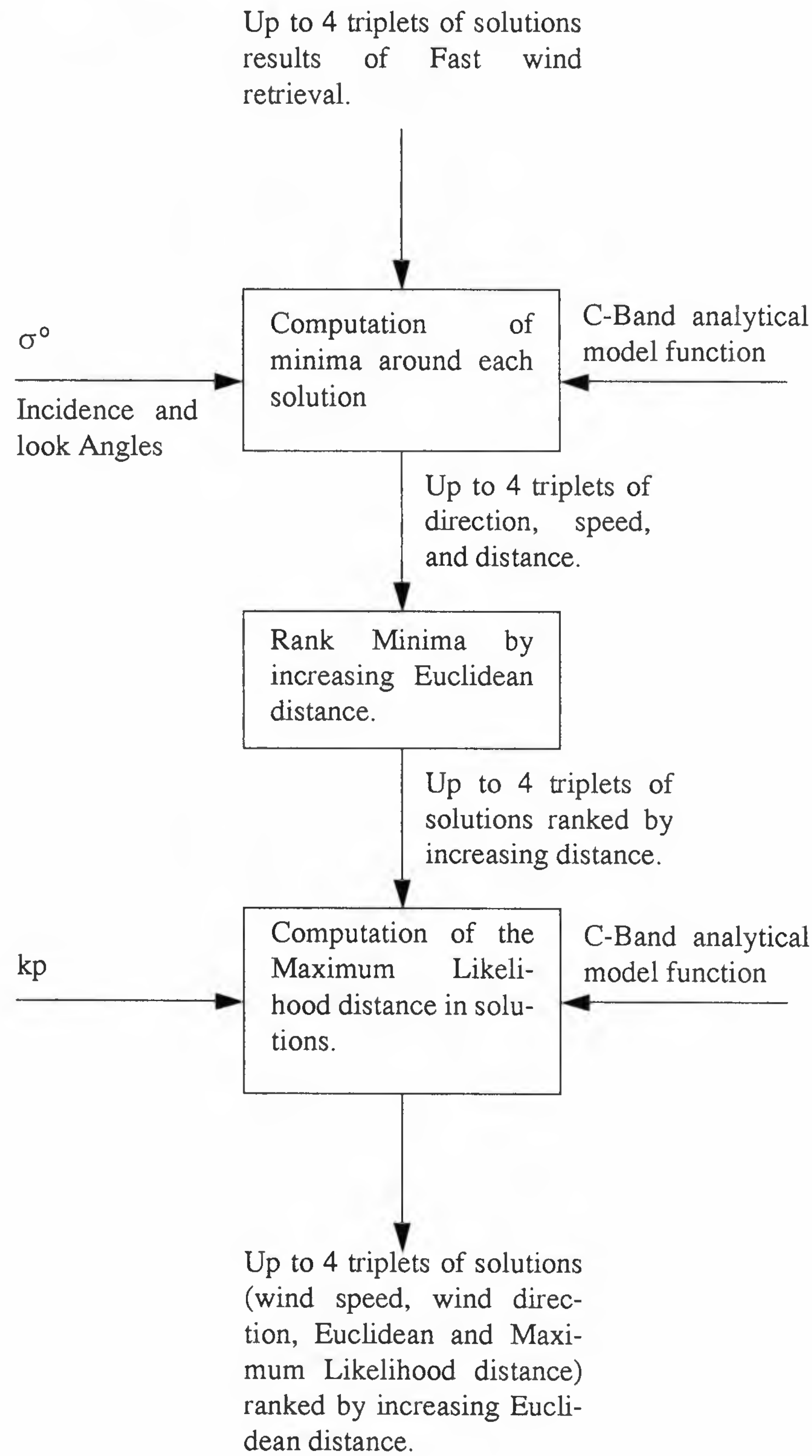

Figure 6.2.a : Precision Wind Processing functional block diagram.

The Data delivered by the raw data up to σ° triplets processing comprises as shown by the block diagram:

- σ° triplets,
- kp triplets,
- node incidence (one per beam).
- look angle (one per beam),
- annotation qualifying the σ° triplets processing:
    - = Measurement validity,
    - = arcing flag,
    - = Land flag,
    - = ice flag.

The definitions of angles (look angle, incidence angle, wind direction) are given in annex A.

The solutions derived from the Fast wind retrieval (maximum of four):

- wind solutions, speed and direction,
- maximum likelihood distance for each solution,
- Euclidean distance for each solution,
- annotations qualifying the fast retrieval processing performed:
    - = Number of solutions.

The model dependant inputs comprises:

- C-Band analytical model function.

External Data are those data required for processing, which are not contained in the output of the raw data up to σ° triplets processing.
This data comprises of:

- control parameters such as:
    - = precision required for wind speed and direction,
    - = maximum number of iterations (Newton-Raphson),
    - = relative precision to stop minimisation (Newton-Raphson),
    - = implementation specific input parameters.

All external data may be updated, if the need arises.

6.4 : Output Parameters

The output data of the Wind retrieval processing are:

- wind solutions, speed and direction (up to four solutions) high resolution,
- maximum likelihood distance for each solution,
- Euclidean distance for each solution,

- annotations qualifying the precision wind retrieval processing performed:
  = Number of solutions,
  = no valid solution computed.
  = relative precision of last stage of minimisation,
  = number of iterations,
  = implementation specific output parameters.

6.5 : Precision wind processing functions

6.5.1 : Computation of Minima around each solution

The computation of the minimum of the Euclidean distance between the measured $\sigma°$ triplet and the model at constant wind direction is performed using a Newton-Raphson method. Here, no table is used, but the $\sigma°$ is computed from the analytical model function (See A-2 and R-2).

The definition of the Euclidean distance is as follows:

$$M^2 = \sum_{i=1}^{3} (\hat{\sigma}_i - \tilde{\sigma}_i)^2$$

where:

- M is the Euclidean distance
- i is the antenna index (1: Fore beam, 2: Mid beam, 3: Aft beam).
- $\hat{\sigma}$ is the measured $\sigma°$ values for the beam i
- $\tilde{\sigma}$ is the $\sigma°$ values computed using the analytical model function for the beam i

The following points have to be noted:

- The analytical model function defines the direction as the azimuth of the wind with respect to beam axis
- Each antenna has a different incidence angle
- Each antenna has a different look angle with respect to the wind direction. The deviation between two antennae beam (Fore-Mid or Mid-Aft) is approximately 45°.

• Geometrical details are given in annex 1.

† For each wind direction from -5° to +5° around each solution provided by the Fast wind retrieval, and with a step of 1°, the wind speed which gives the minimum Euclidean distance is computed. It is assumed that only one minimum exist at a given wind direction. In order to optimise the number of computations, the first minimisation starts with a wind speed solution of the fast wind retrieval. The other minimisation start with the last wind speed computed.

The results of this stage is a table of 4 rows and 3 columns, each row contains the parameter of one minimum, the columns corresponding to the speed, the direction and the Euclidean distance.

If less than four minima are found, the remaining rows are filled with zeroes.

6.5.2 : Ranking of the minima

The up to four minima are ranked (sorted) by increasing value of the Euclidean distance. The first row contains the information (speed, direction, distance) of the lowest Euclidean distance. If less than four solutions are given, the remaining rows are filled with zeroes

6.5.3 : Computation of the maximum likelihood Distance

The distance definition used in the Ambiguity removal part of the algorithm is not the Euclidean distance but the maximum likelihood one, this parameter characterise the probability of having this measured σ° triplet knowing that the correct one is on the model, assuming a Gaussian probability law.

The definition of the maximum likelihood distance is as follows:

$$\mathcal{R} = \sum_{i=1}^{3} \left(\frac{\hat{\sigma}_i - \tilde{\sigma}_i}{kp_i \cdot \tilde{\sigma}_i} \right)^2$$

where:

$\mathcal{R}$ is the maximum likelihood distance
i is the antenna index (1: Fore beam, 2: Mid beam, 3: Aft beam).
$\hat{\sigma}$ is the measured σ° values for the beam i
$\tilde{\sigma}$ is the σ° values computed using the analytical model function for the beam i
kp is the noise characteristics measured for the beam i

The results of this stage is a table of 4 rows and 4 columns, each row contains the parameter of one minimum, the columns corresponding to the speed, the direction, the maximum likelihood distance and the Euclidean distance. If less than four minima are found, the remaining rows are filled with zeroes.

7 : Ambiguity Removal

7.1 : General Description

Wind ambiguity removal selects from the solutions provided for each node those solutions which provide the most consistent overall wind field.

This cannot be done at node level as the probability of having the "correct" solution with a rank 1 (smallest Euclidean distance between the $\sigma°$ triplets measurement and the model) is only around 60%.

The method adopted is to consider the wind field as a whole. This increases the probability of assigning the correct solution at node level.

- † It has been chosen to perform the ambiguity removal over sets of six products which corresponds to strips of 3000 km by 500 km. This proved to be a good trade-off between the ambiguity removal efficiency and the product handling. It has to be noted that when the ambiguity removal fails, all the six products could be affected.

- Throughout the algorithm description, this strip of 3000 km long will be called the "swath".

Statistical analysis made using early version of the C-Band model shows that the correct wind speed and direction is one of the first two solutions given by the wind retrieval. In very few cases (1 or 2 %), the correct solution is of rank 3 or 4.

Another characteristic of the four solutions, is that they are coupled in two pairs, with the elements of a pair being roughly 180 ° apart.

From the above it follows that one can built two coherent wind fields ($\mathcal{A}$ and $\mathcal{B}$) which correspond to wind field blowing at 180 °. By counting the number of rank 1 solution in each field, or by comparing those with an externally provided wind forecast, it is possible to choose the field which is either statistically more likely, or more consistent with the wind forecast.

- In this chapter, "non valid nodes" refers to:
  - nodes over land,
  - nodes over ice,
  - low wind,
  - non valid measurements,
  - non valid solution provided by the wind retrieval.

  The "valid nodes" are nodes which are not "non valid nodes".

7.2 : Functional Block Diagram

An Ambiguity Removal functional block diagram is shown in Figure 7.2.a. It contains the major processing stages as well as the external interfaces. Each block element as well as the interfaces will be addressed in the following sections.

7.3 : Input Parameters

The input parameters entering the Ambiguity Removal processing are categorised as:

- Data delivered by the wind retrieval processing,
- Externally provided data:

The Data delivered by the wind retrieval processing comprises as shown by the block diagram:

- wind speed,
- wind direction,
- Euclidean distance,
- maximum likelihood distance,
- annotations qualifying the wind retrieval processing performed:
  = Number of solutions.
  = Measurement validity,
  = Land flag,
  = ice flag.

The definitions of angles (wind direction) are given in annex A.

External Data are those data required for processing, which are not contained in the output of the raw data up to σ° triplets processing.
This data comprises of:

- control parameters:
  = minimum wind speed for ambiguity removal,
  = maximum likelihood distance accepted for ambiguity removal,
  = minimum number of valid nodes in a contiguous area,
  = minimum number of nodes for statistical mode,
  = minimum ratio of rank 1 for statistical mode
  = minimum value of normalised scalar product for meteorological mode,
  = filtering characteristics,
  = validation distance for forecast,.
  = implementation specific input parameters.
- meteorological forecasts.

† currently, the meteorological forecasts are updated every six hours.

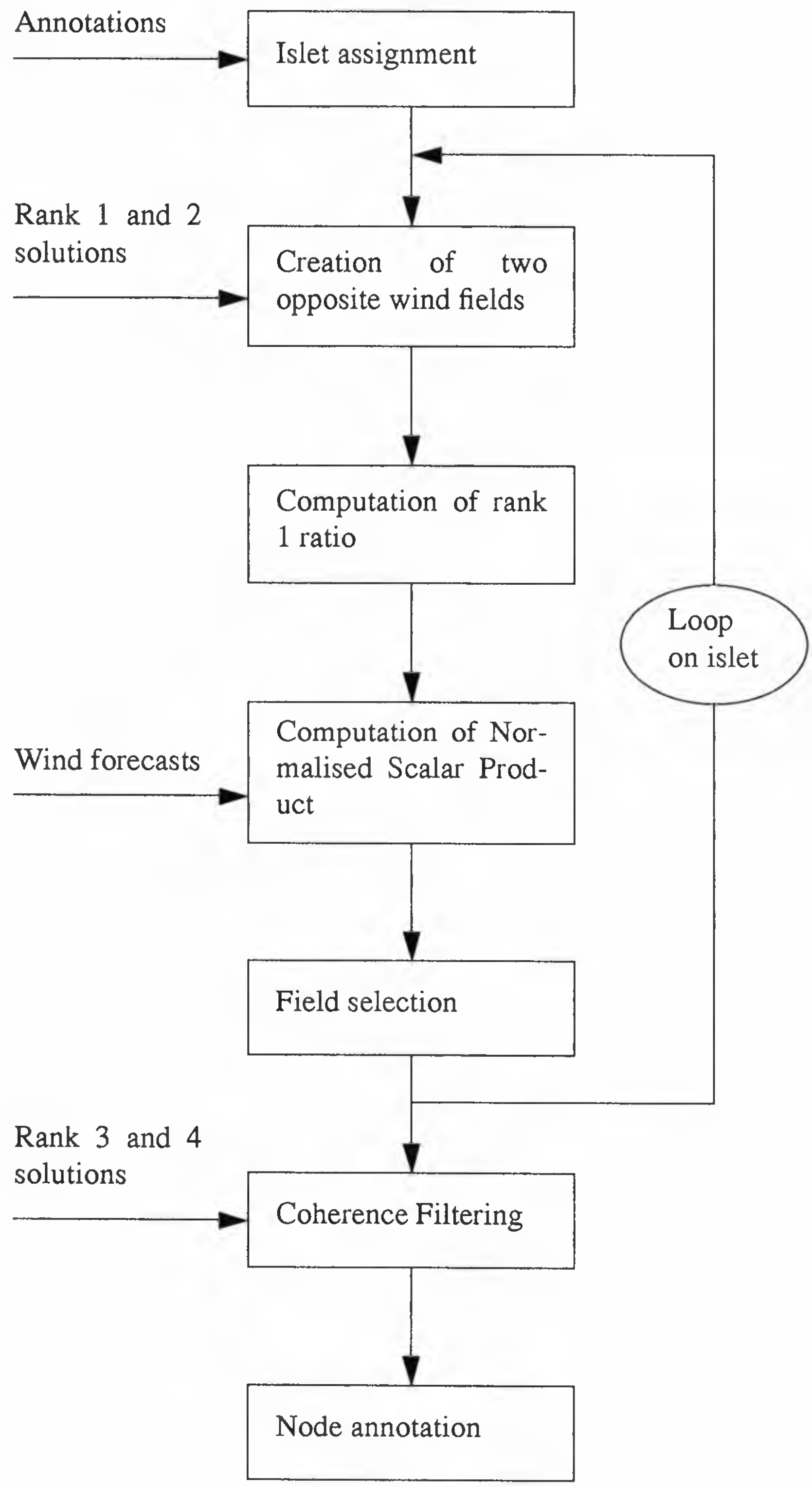

Figure 7.2.a : Ambiguity Removal Processing functional block diagram.

All external data may be updated, if the need arises.

7.4 : Output Parameters

The output data of the ambiguity removal processing are:

- rank of the solution chosen by the ambiguity removal,
- annotations qualifying the processing performed.
  - = ratio of rank 1 in the area for the field $\mathcal{A}$ and $\mathcal{B}$,
  - = normalised scalar product for the field $\mathcal{A}$ and $\mathcal{B}$,
  - = indicator of success flag.

7.5 : Ambiguity Removal Processing functions

7.5.1 : Islet assignment

The ambiguity removal shall be performed on contiguous areas called islets. These islet are separated from each other by areas of "non valid nodes".

At this stage, the algorithm divides the swath in islets.

The result is a mapping of the swath with islets, each valid node being assigned to one islet.

- At low wind speed, the quality of the wind direction is such that it does not make sense to perform the ambiguity removal. The poor quality of the wind direction is due to the very high variability of the wind (structures much smaller than the scatterometer pixel), and to the reduced performance of the C-Band model at low speed.

The following stages of the algorithm are performed on each separate islet.

7.5.2 : Creation of two opposite wind fields

For each islet, two coherent wind fields ($\mathcal{A}$ and $\mathcal{B}$) are built, using the two most probable solutions provided by the wind retrieval algorithm (solution of rank 1 and 2).

the result of this stage is two coherent wind fields ($\mathcal{A}$ and $\mathcal{B}$) which correspond to wind field blowing at 180 °.

† The current implementation starts in one end of the islet by searching a node which has a deviation between its two solutions (rank 1 and 2) greater than 150° (tunable parameter). It takes the rank 1 as a seed for the field $\mathcal{A}$, and the rank two as a seed for the field $\mathcal{B}$. Then for each field, it selects the rank which minimises the direction deviation with respect to the average of the wind direction chosen for the two (or one at the beginning) previous nodes.

7.5.3 : Computation of rank 1 ratio

On each islet and for each of the two fields ($\mathcal{A}$ and $\mathcal{B}$), the total number of nodes ($\mathcal{N}t$) and the number of rank1 node (respectively $\mathcal{N}a$ and $\mathcal{N}b$) are computed. The ratios $\mathcal{N}a/\mathcal{N}t$ and $\mathcal{N}b/\mathcal{N}t$ characterise the quality of each field.

The result of this stage is two ratio characterising both fields ($\mathcal{A}$ and $\mathcal{B}$).

- Note that $\mathcal{N}a/\mathcal{N}t = 1-\mathcal{N}b/\mathcal{N}t$.

† The current implementation computes these values only for certain nodes having the rank 1 solution in certain directional sectors (18°-42°, 138°-162°, 210°-234° and 306°-330°) computed with respect to the satellite track. This increases the probability of having a the correct solution as rank 1. In that case, the ratios $\mathcal{N}a/\mathcal{N}t$ and $\mathcal{N}b/\mathcal{N}t$ are not related.

7.5.4 : Computation of Normalised Scalar Product

On each islet and for each of the two fields ($\mathcal{A}$ and $\mathcal{B}$), the Normalised Scalar Product S is computed.

This parameter gives information on the correlation between the wind given in each of the two fields and the forecast provided, it can take value between -1 and +1, corresponding respectively to full correlation and anti-correlation (i.e.: 0° and 180° deviation at each node) of the field and the forecast.

This product is computed using only co-located forecast and scatterometer data, where co-located means both geographical and temporal overlapping of the data with the forecast. All other nodes are rejected.

If less than one collocation is available, the Normalised Scalar Product is set to -1 (field and forecast anti-correlated).

The definition of the Normalised Scalar Product is:

$$S = \frac{\sum V_m \cdot V_s \cdot \cos(D_m - D_s)}{\sum V_m \cdot V_s}$$

where:

S is the Normalised Scalar Product
V_m is the wind speed given by the forecast
D_m is the wind direction given by the forecast
V_s is the wind speed given by the scatterometer
D_s is the wind direction given by the scatterometer

- Nominally, the two Normalised Scalar Product (for field $\mathcal{A}$ and $\mathcal{B}$) have opposite signs

The result of this stage is two $\mathcal{S}$ values characterising both fields ($\mathcal{A}$ and $\mathcal{B}$).

7.5.5 : Field selection

On each islet , the best field is selected.

The selection of the field is based on the values of the rank 1 ratio and of the Normalised Scalar Product.

The criteria for selection are:
- Normalised Scalar Product greater than the acceptance criteria, or,
- rank 1 ratio greater than acceptance criteria and Normalised Scalar Product positive.

If none of the criteria is verified, the ambiguity removal is unsuccessful. In that case, the rank 1 solution is provided in the product, and the corresponding annotation set.

7.5.6 : Coherence Filtering

After applying the above coarse ambiguity removal on each islet (using rank 1 and 2 only), a filter is applied in order to improve the wind field by introducing rank 3 and 4 where appropriate.

† This is performed by selecting for each node the rank which minimises the average deviation with respect to the eight neighbours. Two passes are applied; in the first one only changes greater than a threshold are allowed in order to correct first for bigger errors in the field.

The result of the stage is a wind field with improved coherence.

7.5.7 : Node Annotation

For each node of the swath, the rank of the solution chosen is reported as well as the two values of the Normalised Scalar Product and of the rank 1 ratio.

Annex A

Definition of Angles

1 : wind azimuth

In the analytical model function, the wind direction is the azimuth of the wind with respect to beam axis i.e. the angle measure between the beam axis and the direction from where the wind is blowing from.

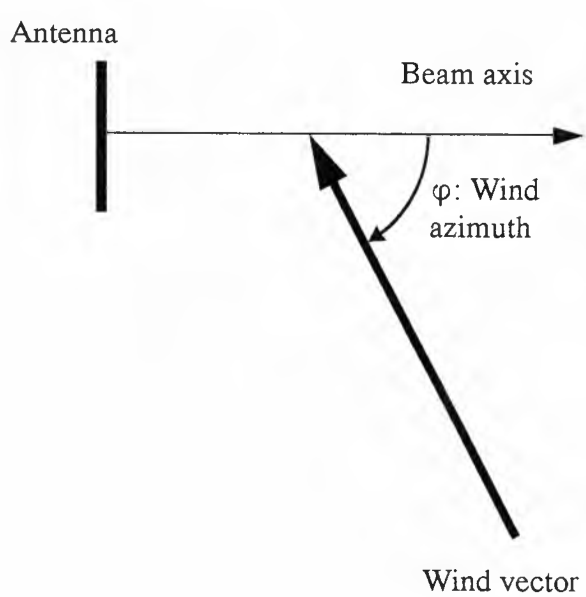

Figure 1.1 : Definition of the wind azimuth

The model is a symetrical function with respect to the wind azimuth:

$$\sigma^o = f(V, \varphi, \theta) = f(V, -\varphi, \theta)$$

2 : Antenna look angle

The antenna look angle is measured clockwise at each node. It is the angle between the north and the antenna beam (from the node to the satellite).

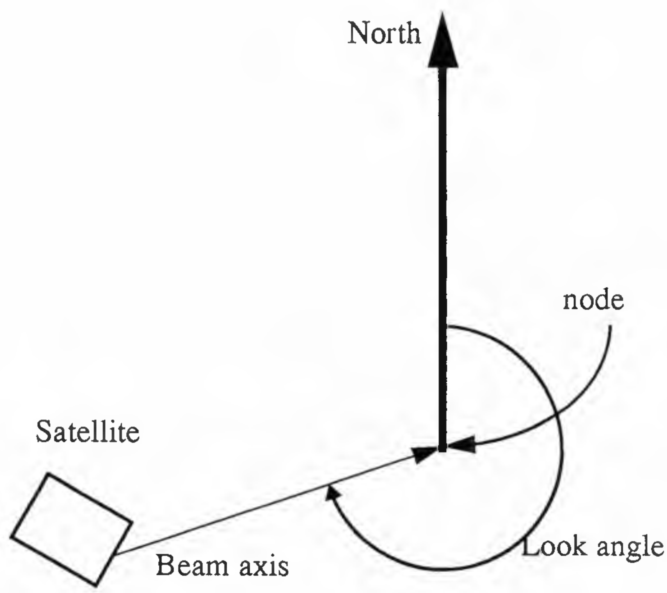

Figure 2.1 : Definition of the look angle

The figure shows the geometry for the Aft beam, during a descending pass.

3 : Incidence angle

The incidence angle is the angle measured at the node, clockwise, between the vertical at the node and the beam axis:

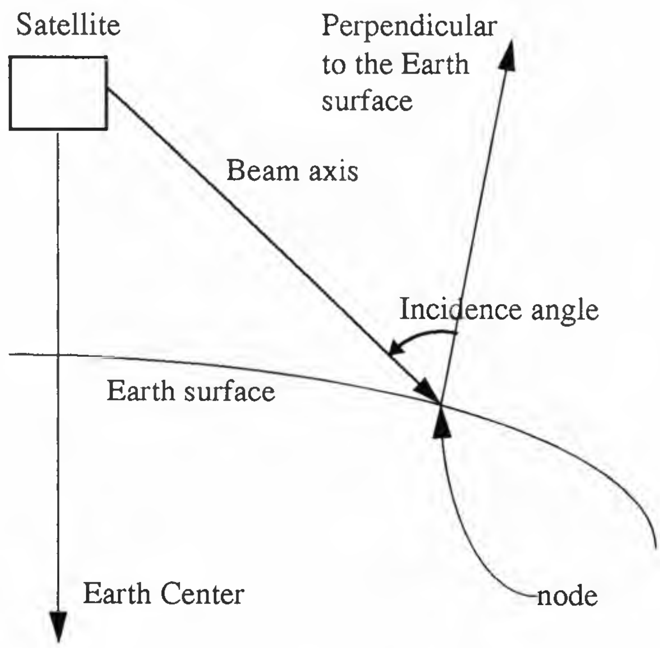

Figure 3.1 : Definition of the incidence angle

4 : Satellite heading

The Satellite headin gis the angle measured on the ground between north and the velocity of the satellite

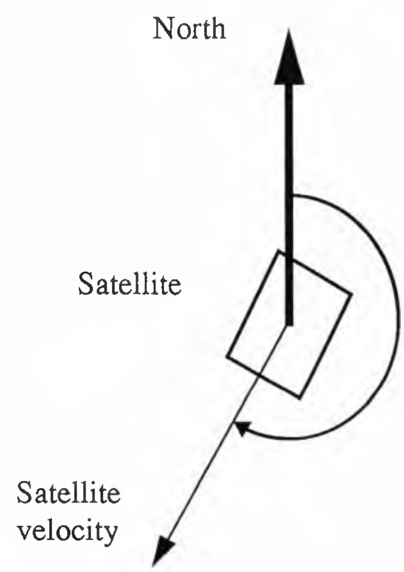

Figure 4.1 : Definition of the Satellite Heading

The figure shows the geometry during a descending pass.

5 : Definition of angles in the actual version of the wind software.

The chapter describes the different angles as they are used in the current implementation of the wind software.

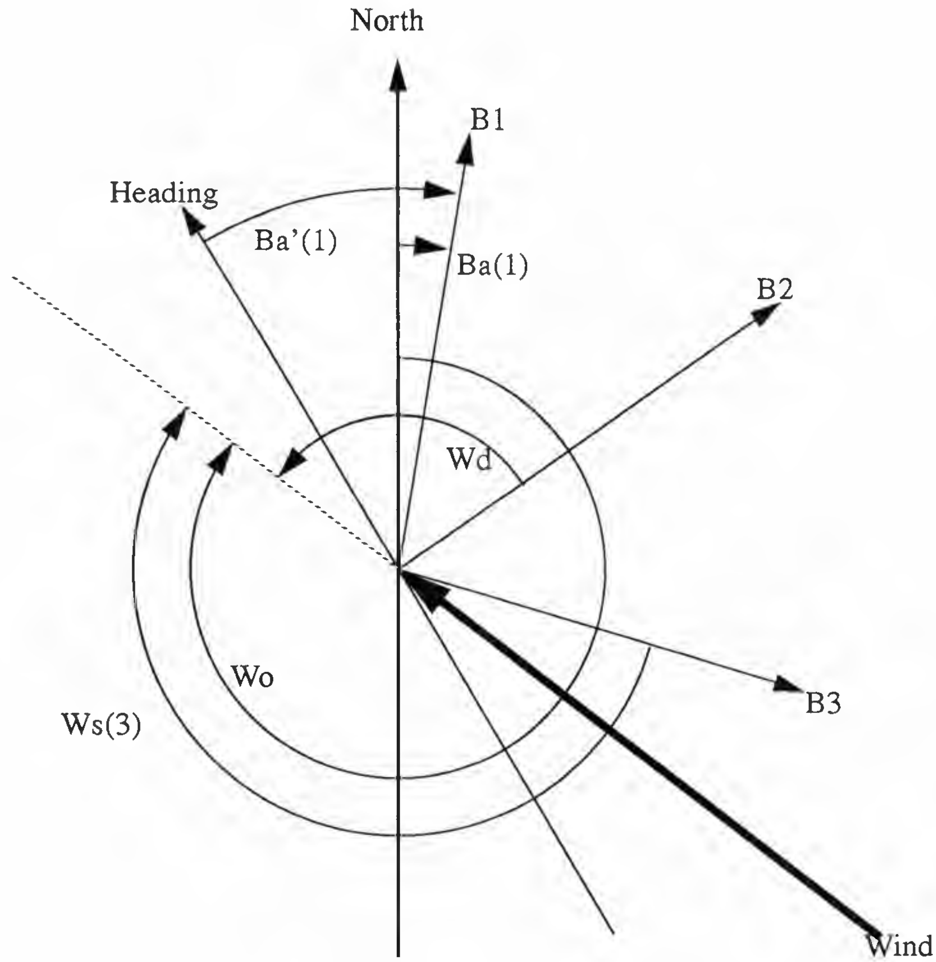

Figure 5.1 : Wind software angles definition

B1 = Fore beam Direction
B2 = Mid beam Direction
B3 = Aft beam Direction

Ba(i) = beam 'i' Azimuth Angle (measured clockwise from the north)
Ba'(i) = beam 'i' Azimuth Angle (measured clockwise from the satellite heading

Wo = Wind Direction (measured clockwise from North)
Wd = Wind Direction (measured anticlockwise from the mid beam)
Ws(i) = Wind Direction (measured clockwise from the beam 'i')

For each beam:

$$Ws(i) = Wo - Ba(i)$$

Wind direction is determined in 'Beam Centred Coordinates'. Furthermore, beam angles are re-defined relative to the beam, which is set at 90° to the heading.

$Ba'(i) = Ba(i) - Ba(2) + 90°$ Applied in module WIND before calling WINRET

Reformulation Ws(i) in terms of Wd gives:

$|Ws(i)| = |Wd + Ba'(i) - 90°|$ Applied within RESTAB / RESOL

The absolute value of Ws(i) is used as the behaviour of Ws is symmetric.
So the three beam centred directions can be derived for the trial values of Wd, the optimum value of which is returned by RESTAB / RESOL.

Wd is now converted to North Orientated coordinates:

$$Wo = Ba(2) - Wd$$

This is applied in two steps:

$Wt = 90° - Wd$ Applied in WINRET
Where Wt is the Wind direction wrt Heading

$Wo = Wt + Ba(2) - 90°$ Applied in LVDOUT

Annex B

Euclidean and Maximum Likelihood distances

1 : Euclidean distance

The definition of the Euclidean distance is as follows:

$$M^2 = \sum_{i=1}^{3} (\hat{\sigma}_i - \tilde{\sigma}_i)^2$$

where:

- M is the Euclidean distance
- i is the antenna index (1: Fore beam, 2: Mid beam, 3: Aft beam).
- $\hat{\sigma}$ is the measured σ° values for the beam i
- $\tilde{\sigma}$ is the σ° values computed using the analytical model function for the beam i

This is the "real" distance one can measure between the measured σ° values and the theoretical one lying on the model.

This distance has to be used during the wind retrieval in order to have a correct distribution of the wind direction.

When the maximum likelihood distance is used, some direction are not given in output (45°, 135°, 225° and 315° with respect to the satellite track). The resulting wind field has patches of nearly constant wind direction and jumps of direction between two patches (granularity).

2 : Maximum Likelihood distance

The definition of the maximum likelihood distance is as follows:

$$\mathcal{R} = \sum_{i=1}^{3} \left(\frac{\hat{\sigma}_i - \tilde{\sigma}_i}{kp_i \cdot \tilde{\sigma}_i} \right)^2$$

where:

- $\mathcal{R}$ is the maximum likelihood distance
- i is the antenna index (1: Fore beam, 2: Mid beam, 3: Aft beam).
- $\hat{\sigma}$ is the measured $\sigma°$ value for the beam i
- $\tilde{\sigma}$ is the $\sigma°$ value computed with the analytical model function for the beam i
- kp is the noise characteristics measured for the beam i

The maximum likelihood distance is derived from the definition of a Gaussian probability law.

The noise attached to each individual $\sigma°$ follows a Gaussian law. This assumption is valid because each $\sigma°$ is the average of a big number of individual measurements.

If the measured $\hat{\sigma}$, is subject to a multiplicative Gaussian noise of standard deviation $Kp \cdot \tilde{\sigma}$, where $\tilde{\sigma}$ is the noiseless value of $\sigma°$, then the density of probability of having this measurement is:

$$p = \frac{1}{\sqrt{2\pi} Kp \cdot \tilde{\sigma}} e^{-\frac{1}{2}\left(\frac{\hat{\sigma} - \tilde{\sigma}}{Kp \cdot \tilde{\sigma}}\right)^2}$$

As the three measurement are independent, their noise are uncorrelated. Therefore, the density of probability of the $\sigma°$ triplet is the product of the three individual densities:

$$\mathcal{P} = \prod_{i=1}^{3} p_i = \frac{1}{\sqrt[3]{2\pi} \prod_{i=1}^{3} (Kp_i \cdot \tilde{\sigma}_i)} e^{-\frac{1}{2}\sum_{i=1}^{3}\left(\frac{\hat{\sigma}_i - \tilde{\sigma}_i}{Kp_i \cdot \tilde{\sigma}_i}\right)^2}$$

The solution which makes $\mathcal{P}$ maximum, minimises the exponent which is to the Maximum likelihood distance.

As the theoretical C-Band model is highly non linear, this definition of the distance does not always provide the best results in fact the solution are more frequently found with a direction which correspond to wind parallel to or perpendicular to the Mid beam.

This distance gives information in a space which is independent of the $\sigma°$ value as the noise standard deviation is proportional to the $\sigma°$. Using this distance a simple test allows to detect nodes “too far” from the model (a simple threshold on the maximum likelihood distance is necessary). It would be nearly impossible to do the same with the Euclidean distance.

Annex C

WIND software structure

1 : Routine WIND

```
C--------------------------------------------------------------------------
C
C         Name : WIND
C
C         Summary
C         -------
C
C         Function : Wind extraction and ambiguity removal subroutine
C
C         This is the main subroutine. Based on the input control array
C         contr, this routine will initialise, retrieve wind, and/or
C         perform ambiguity removal upon the input sigma0 triplets.
C
C         If Contr = 5 , then the processing is initialised.
C         If Contr = 4 , then processing has stopped and only output file
C                        status is checked.
C         If Contr = 3 , initiates process termination.
C         If Contr = 2 , is a 'warm start' with vaild output arrays
C         If Contr = 1 , is a 'warm start' with valid tables
C                        1 & 2 are only used in test mode. Not opperationally.
C
C         INPUTS:
C                        CONTR      Control code defined above
C                        ZSO        Array of Sigma0 triplets
C                        ZKP        Array of associated noise estimations
C                        ZBA        Array of associated beam azimuth angles
C                        ZAI        Array of associated beam incidence angles
C                        ZIFLAG     Array of associated Sigma0 processing flags
C                        ZPARAM     Array of associated Parametric data
C
C         OUTPUTS:
```

```
C                   IERR       Processing error status
C                   STAT       Output file status
C
C
C          Routines called
C          ---------------
C
C      WIND - I---> TABLE
C             I
C             I---> INITIAL
C             I
C             I---> WINRET    I--> CALVAR
C             I               I
C             I               I--> CALCOEF --> CALSIG
C             I               I
C             I               I--> RESTAB     I--> VITAPTR --> CALSIG
C             I               I               I
C             I               I               I--> MINTAB ---> CALDIT
C             I               I               I
C             I               I               I--> MINIMA
C             I               I
C             I               I--> RESOL      I---> VITAPTR --> CALSIG
C             I               I               I
C             I               I               I---> MINVIT ---> CALDIS -> CALSIG
C             I               I               I
C             I               I               I---> MINIMA
C             I               I
C             I               I--> CALDIS ---> CALSIG
C             I
C             I---> LVDOUT    I--> ILOTAGE --> REARG
C             I               I
C             I               I--> LVDOUT3   I-> CHOIX ----> MOYENNE
C             I               I
C             I               I-> LVDMETEO
C             I               I
C             I               I-> COHERENCE
C             I
C             I---> FICHIER
C
C
C
C------------------------------------------------------------------------
C
```

2 : Routine TABLE

```
C--------------------------------------------------------------------------
C
C Name : TABLE
C
C            Summary
C            -------
C
C
C            It initializes the parameters of WINRET and LVDOUT using
C            "commons" for fixed parameters and reading file
C            PARAMETER.DAT for others. The Wind retrieval analytical
C            model parameters are also initialised.
C
C            It also reads the differents tables used for inversion
C            and ambiguity removal :
C
C            TCOS (410)            cosinus table (WINRET)
C            TAB (242165)          Wind Model table CMOD4 (WINRET)
C            METEO (2,241,480)     Meteorological field
C                                  (degres x degres) (LVDOUT)
C
C
C            Dimensions in latitude and longitude of the meteorological
C            wind table ( METTABLE ) are set with an instruction
C            parameter. MET1 and MET2 must be equal to METDIM(1)
C            and METDIM(2) ( respectively ) read in the file
C            PARAMETER.DAT.
C
C
C            Routines called
C            ---------------
C
C            NONE
C
C--------------------------------------------------------------------------
C
```

3 : Routine INITIAL

```
C--------------------------------------------------------------------------
C
C          Name : INITIAL
C
C          Summary
C          -------
C
C
C          It initalizes the various parameters for a new swath
C          independent of the last one.
C
C
C          OUTPUT:
C                     DEBUT     First line of swath
C                     LIGNE     Line number within data set
C
C          Routines called
C          ---------------
C
C          NONE
C
C--------------------------------------------------------------------------
C
```

4 : Routine WINRET

```
C-------------------------------------------------------------------------
C
C         Name : WINRET
C
C         Summary
C         -------
C
C         This is the Sigma0 to wind inversion routine. After Initialising
C         the analytical model function, and testing the Sigma0 triplet
C         validity, the four principle solutions of the model are recovered
C         either by the fast table driven mode (RESTAB), or the slower precision
C         iterative mode (RESOL). After this stage the residual values of the
C         solutions are converted to Maximum Likelihood values.
C
C         INPUT:
C                   SOT       Measurement triplet
C                   AIT       Incidence angle
C                   BAT       Beam Azimuth Angle
C                   KPT       Standard error
C                   IFLA      Measurement informations
C
C         OUTPUT:
C                   NSOL      Number of solutions found
C                   VSOL      Windspeed in m/s
C                   DSOL      Direction in degres
C                   RSOL      Resulting distance
C                   NSOL      Number of solutions
C                   NITERM    Number of iterations used (if appropriate)
C
C
C         Routines called
C         ---------------
C
C     WINRET  I--> CALVAR
C             I
C             I--> CALCOEF ----> CALSIG
C             I
C             I--> RESTAB  I---> VITAPTR ---> CALSIG
C             I            I---> MINTAB ----> CALDIT
C             I            I---> MINIMA
C             I
C             I--> RESOL   I---> VITAPTR ---> CALSIG
C             I            I---> MINVIT ---> CALDIS ---> CALSIG
C             I            I---> MINIMA
```

```
C                  I
C                  I--> CALDIS ----> CALSIG
C
C-----------------------------------------------------------------------
C
```

5 : Routine CALVAR

```
C--------------------------------------------------------------------------
C
C          Name : CALVAR
C
C          Summary
C          -------
C
C          Evaluation of the parameters depending only of the incidence angle
C          This subroutine must be called before using CALCOEF.
C
C          INPUTS:
C                    THETA      Incidence angle of beams
C                    FLAG       Beam validity flags
C
C
C          Routine called
C          --------------
C
C          NONE
C
C
C--------------------------------------------------------------------------
C
```

6 : Routine CALCOEF

```
C-------------------------------------------------------------------------
C
C           Name : CALCOEF
C
C           Summary
C           -------
C
C           Evaluates the three Sigma0 for a given set of incidence angles,
C           Beam azimuth angles, and a wind vector. NOTE the incidence angle
C           part of the analytical model function must have beam initiated
C           by a call the CALVAR.
C
C           INPUTS:
C                       V           Wind speed
C                       PHI         Wind direction
C                       IBA         Beam azimuth angles
C
C           OUTPUTS:
C                       SIGMA0      Analytical model solution
C
C           Routines called
C           ---------------
C
C           CALSIG
C
C
C
C-------------------------------------------------------------------------
C
```

7 : Routine CALSIG

```
C--------------------------------------------------------------------------
C
C        Name : CALSIG
C
C        Summary
C        -------
C
C        Calculation of the sigma0 for a given speed and direction
C        using the CMOD6 E1 C-band model. Incidence angle part of the
C        analytical model function must have been initiated with a call
C        to CALVAR
C
C        INPUTS:
C                 SPEED      Wind speed
C                 PHI        Wind direction
C                 B_ANGLE    Beam azimuth angle
C                 ANT        Antenna ( 1 = Fore, 2 = Mid, 3 = Aft )
C
C        OUTPUTS:
C                 SIGMA0     Analytical model solution
C
C        Routine called
C        --------------
C
C        NONE
C
C
C--------------------------------------------------------------------------
C
```

8 : Routine RESTAB

```
C--------------------------------------------------------------------------
C
C Name : RESTAB
C
C           Summary
C           -------
C
C           This routine is the fast table driven wind retrieval algorithm.
C           Possible solutions are isolated for the full 360 degrees. The top six
C           solutions (If 6 exist) are then ranked in order of decreasing
C           probabilty and returned.
C
C           INPUTS:
C                     SIGM        Measured Sigma0
C                     TETA Incidence Angles
C                     IBA Beam Azimuth Angles
C                     EK Standard Error (Kp)
C                     JFLAG Measurement Flags
C
C
C           OUTPUTS:
C                     VOUT Wind Speed
C                     PHIOUT Wind Direction
C                     DOUT Distances From SIGM To Surface
C                     NSOL Number Of Possible Solutions
C
C           Routines called
C           ---------------
C
C     RESTAB      I --> VITAPTR --> CALSIG
C                 I
C                 I --> MINTAB ---> CALDIT
C                 I
C                 I --> MINIMA
C
C--------------------------------------------------------------------------
C
```

9 : Routine VITAPTR

```
C---------------------------------------------------------------------------
C
C          Name : VITAPTR
C
C          Summary
C          -------
C
C          Tests the validity of the Sigma0 triplet. Returning the seed
C          speed for calculation.
C
C          INPUTS:
C                    SIGMA0     Measured sigma0
C                    THETA      Beam incidences angles (nolonger used)
C                    FLAG       Beam quality flags
C                    IBA        Beam azimuth angles
C
C          OUTPUTS:
C                    SPEED      Seed wind speed
C
C          Routine called
C          -------------
C
C          CALSIG
C
C
C---------------------------------------------------------------------------
C
```

10 : Routine MINTAB

```
C-------------------------------------------------------------------------
C
C          Name : MINTAB
C
C          Summary
C          -------
C
C
C          Minimisations of the solution space at constant angle using
C          the Sigma0 table.
C
C          INPUTS:
C                      SIGM        Measured Sigma0 Triplet
C                      IBA         Beam azimuth angles
C                      EK          Standard errors
C                      IPHI        Wind direction to minimise along
C                      KVS         Search step and initial direction
C
C          OUTPUTS:
C                      IV          Speed index ( speed = (iv+1)/2)
C                      DIS         Distance form model surface
C
C          Routines called
C          ---------------
C
C          CALDIT
C
C
C
C-------------------------------------------------------------------------
C
```

11 : Routine CALDIT

```
C---------------------------------------------------------------------------
C
C          Name : CALDIT
C
C          Summary
C          -------
C
C
C          Calculates the Euclidean distance between the Measured Sigma0 Triplet
C          and the Table entry selected.
C
C          INPUTS:
C                    SIGM        Measured Sigma0 Triplet
C                    EK          Standard Errors ( nolonger used)
C                    IV1         Speed index for table ( rest of index passed by common)
C
C          OUTPUTS:
C                    D           Euclidean Distance for model surface
C
C          Routines called
C          ---------------
C
C          NONE
C
C
C
C---------------------------------------------------------------------------
C
```

12 : Routine MINIMA

```
C------------------------------------------------------------------------
C
C          Name : MINIMA
C
C          Summary
C          -------
C
C
C          Locates the top ten minima in the linear array DIS which contains the
C          best wind vector consistant with the input Sigma0 triplet at every
C          direction.
C
C          INPUTS:
C                    DIS          Table Of Distances D
C                    NBMIN        Dimension Of The Table
C
C          OUTPUTS:
C                    NBMIN        Number Of Minima Found
C                    IMIN         Table Containing The Indices Of Minima
C
C
C          Routines called
C          ---------------
C
C          NONE
C
C
C
C------------------------------------------------------------------------
C
```

13 : Routine RESOL

```
C--------------------------------------------------------------------------
C
C          Name : RESOL
C
C          Summary
C          -------
C
C
C          This routine is the precision wind retrieval algorithm.
C          Possible solutions are isolated for the full 360 degrees. The top six
C          solutions (If 6 exist) are then ranked in order of decreasing
C          probabilty and returned.
C
C          INPUTS:
C                     SIGM       Measured Sigma0
C                     TETA       Incidence Angles
C                     IBA        Beam Azimuth Angles
C                     EK         Standard Error (Kp)
C                     JFLAG      Measurement Flags
C
C
C          OUTPUTS:
C                     VOUT       Wind Speed
C                     PHIOUT     Wind Direction
C                     DOUT       Distances From SIGM To Surface
C                     NSOL       Number Of Possible Solutions
C                     NITERM     Number of iterations used
C
C
C          Routines called
C          ---------------
C
C     RESOL     I---> VITAPTR ---> CALSIG
C               I
C               I---> MINVIT ---> CALDIS ---> CALSIG
C               I
C               I---> MINIMA
C
C
C
C--------------------------------------------------------------------------
C
```

14 : Routine MINVIT

```
C--------------------------------------------------------------------------
C
C           Name : MINVIT
C
C           Summary
C           -------
C
C
C           Minimisation of the solution space at constant angle using
C           the analytic model function and an approximate Newton-Raphson
C           iteration.
C
C           INPUTS:
C                      SIGM       Measured Sigma0 Triplet
C                      IBA        Beam azimuth angles
C                      EK         Standard errors
C                      IPHI       Wind direction to minimise along
C                      JFLAG      Beam validity flags
C
C           OUTPUTS:
C                      VMIN       Wind speed
C                      DMIN       Distance from model surface
C                      NITER      Number of iterations
C
C
C
C           Routines called
C           ---------------
C
C           CALDIS
C
C
C
C--------------------------------------------------------------------------
C
```

15 : Routine CALDIS

```
C------------------------------------------------------------------------
C
C          Name : CALDIS
C
C          Summary
C          -------
C
C          Computes either the Euclidean Distance, or the Maximum Likeihood
C          Distance of the measured Sigma0 triplet from the Analytical Model
C          surface.
C
C          INPUTS:
C                    SIGM       Measured Sigma0 Triplet
C                    EK         Standard errors
C                    JFLAG      Beam quality flags
C                    IPHI       Wind direction
C                    V          Wind velocity
C                    IBA        Beam Azimuth angle
C                    P_FLAG     Distance type flag
C
C          OUTPUTS:
C                    DIST       Distance of measured Sigma0 from model surface
C
C          Routines called
C          ---------------
C
C          CALSIG
C
C
C------------------------------------------------------------------------
C
```

16 : Routine LVDOUT

```
C-------------------------------------------------------------------------
C
C          Name : LVDOUT
C
C          Summary
C          -------
C
C
C          Main Ambiguity removal routine. The swath (6 products) is
C          divide into contiguous areas with ILOTAGE. Then 3 beam
C          ambiguity removal is performed.
C
C          INPUTS:
C                         DEBUT      The first valid output line
C                         FIN        The last valid output line
C                         LIGNE      Length of the swath
C
C          OUTPUTS:
C                         ETATS      Outfile status
C
C          Routines called
C          ---------------
C
C     LVDOUT       I--> ILOTAGE --> REARG
C                  I
C                  I--> LVDOUT3 I-> CHOIX ----> MOYENNE
C                  I
C                  I-> LVDMETEO
C                  I
C                  I-> COHERENCE
C
C
C
C-------------------------------------------------------------------------
C
```

17 : Routine ILOTAGE

```
C-----------------------------------------------------------------------
C
C          Name : ILOTAGE
C
C          Summary
C          -------
C
C          This subroutine performs a determination of the type of
C          zone encountered along the swath ( with LFAUCH length of
C          the swath and NBZO number of zone)
C          ZONE and ILOT are respectively the tables with in entry
C          the type of zone and in output the number assigned to it
C          for each point. LIMIT is a table with boundary or type
C          of each unit
C
C          Way of processing depend of TYPE value
C          Three ways of proccessing may be encountered.
C
C                    1 : normal classification with boundary determination
C
C                    2 : normal classification with calculation of the type
C                              of each zone.
C
C                    3 : classification without taking in account the
C                              diagonals for points with the type of zone
C                              equal to 4.
C
C          INPUTS:
C                    LFAUCH    Swath length
C                    TYPE      Classification type
C                    ZONE      Zone type ( 3 = 3 beam, 2= 2 beam, 4 = other)
C          OUTPUTS:
C                    NBZO      Number of zones found
C                    ILOT      Zone number for each node
C                    LIMIT     Zone details
C
C          Routines called
C          ---------------
C
C          ILOTAGE --> REARG
C
C
C-----------------------------------------------------------------------
C
```

18 : Routine REARG

```
C--------------------------------------------------------------------------
C
C          Name : REARG
C
C          Summary
C          -------
C
C
C          This subroutine renumbers the points I2 to I1 in the
C          array ILOT. This will be done from line L0 backward,
C          and processed all modification needed.
C
C          INPUTS:
C                        ILOT        Zone numbers for each node
C                        L0          Last row to be treated
C                        I1          New zone number
C                        I2          previous zone number
C                        LFAUCH      Swath length
C          OUTPUTS:
C
C          Routines called
C          ---------------
C
C          NONE
C
C
C
C--------------------------------------------------------------------------
C
```

19 : Routine LVDOUT3

```
C-----------------------------------------------------------------------
C
C           Name : LVDOUT3
C
C           Summary
C           -------
C
C
C           This subroutine performs ambiguity removal on 3 beam areas.
C           First of all a good node is found and a wind field based on its
C           rank 1 vector is built. If autonomous ambiguity removal is allowed
C           then the field is analysed. If it is not good the wind field based on
C           rank 2 is built and tested. If it is not good meteological ambiguity
C           removal is tried on the two fields. If a good solution is reached then
C           rank 3 & 4 are introduced where necessary for coherence.
C
C           INPUTS:
C                       DEBU      First row of islet
C                       FIN       Last row of islet
C                       NI        Islet number
C                       ERRMET    Meteo table flag
C                       LVDEXE    Execution mode ( 1 = auto & meteo, 2 = meteo)
C
C           OUTPUTS:
C
C
C           Routines called
C           ---------------
C
C     LVDOUT3     I----> CHOIX ---------> MOYENNE
C                 I
C                 I----> LVDMETEO
C                 I
C                 I----> COHERENCE
C
C
C
C-----------------------------------------------------------------------
C
```

20 : Routine CHOIX

```
C------------------------------------------------------------------------
C
C          Name : CHOIX
C
C          Summary
C          -------
C
C          This subroutine makes a choice,in a table DIR(2,19,lfauch)
C          filled with two directions ( at 180 each ). DIR(1,i,j)
C          and DIR(2,i,j). It selects the most appropriate value
C          coherent with the field already calculated. And takes
C          in account the modifications in the array RANG.
C
C          CHOIX begins on the last point of the last line. The
C          COHERENCE will go in the other direction to treat
C          shadow zones.
C
C
C          INPUTS:
C                    DEBU      First row of islet
C                    FIN       Last row of islet
C                    NI        Islet number
C                    IP        Seed point rank (1 or 2)
C
C          OUTPUTS:
C
C          Routines called
C          ---------------
C
C          MOYENNE
C
C
C
C------------------------------------------------------------------------
C
```

21 : Routine MOYENNE

```
C-----------------------------------------------------------------------
C
C         Name : MOYENNE
C
C         Summary
C         -------
C
C         Function processing the mean of two angles.
C         If the difference between the two points
C         is greater than 90 degrees, it does not
C         take into account point having less than
C         90 degrees between its two rank.
C
C         INPUTS:
C                   IP        Seed rank value (nolonger used)
C                   I1        Point 1 coordinate
C                   J1        Point 1 coordinate
C                   I2        Point 2 coordinate
C                   J2        Point 2 coordinate
C
C         OUTPUTS:
C
C         Routines called
C         ---------------
C
C         NONE
C
C
C
C-----------------------------------------------------------------------
C
```

22 : Routine LVDMETEO

```
C-------------------------------------------------------------------------
C
C       Name : LVDMETEO
C
C       Summary
C       -------
C
C       This subroutine processes the ambiguity removal on
C       the swath points giving informations on the threes
C       beams and compares the field with a meteorological
C       field from an other source.
C
C       INPUTS:
C                   DEBU      First row of islet
C                   FIN       Last row of islet
C                   NI        Islet number
C                   ERRMET    Meteo file flag
C
C       OUTPUTS:
C
C       Routines called
C       ---------------
C
C       NONE
C
C
C
C-------------------------------------------------------------------------
C
```

23 : Routine COHERENCE

```
C--------------------------------------------------------------------------
C
C         Name : COHERENCE
C
C         Summary
C         -------
C
C         Subroutine taking account the incoherencies in
C         direction over a part of the swath.
C
C         INPUTS:
C                 DEBU     First row of islet
C                 FIN      Last row of islet
C                 NI       Islet number
C                 TYPE     Type of coherence checkking ( 1 = Rank 1, 2 only)
C
C         OUTPUTS:
C
C         Routine called
C         --------------
C
C         None
C
C
C--------------------------------------------------------------------------
C
```

24 : Routine FICHIER

```
C-----------------------------------------------------------------------
C
C          Name : FICHIER
C
C          Summary
C          -------
C
C
C          This subroutine manages the status of all output files and
C          signal to calling program via
C                    -> stat(1) if a file is complete (1) or not (0)
C                    -> stat(2) the NO. of file
C
C          Etats(i) indicate if a file exist (1) or not (0).
C
C          INPUTS:
C
C          OUTPUTS:
C                    STAT       Output control array
C                    ETATS      Output file status array
C
C          Routines called
C          ---------------
C
C          NONE
C
C
C
C-----------------------------------------------------------------------
```

Annex D

Quantisation Noise

This annex describes the results obtained on the noise introduced by the quantisation of the C-Band model table

These results are partly based on the work made by CREO and explained in R-4.

In this annex the variance will be called v, and the standard deviation s.

1 : Variance due to quantisation

The definition of the variance is:

$$v = \frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x}_i)^2$$

Where: $x_i = \bar{x}_i \pm \varepsilon$, and: $\varepsilon \in [-\frac{\delta}{2}, \frac{\delta}{2}]$

Therefore, the variance is:

$$v = \frac{1}{N}\sum_{i=1}^{N}(\bar{x}_i \pm \varepsilon_i - \bar{x}_i)^2 = \frac{1}{N}\sum_{i=1}^{N}\varepsilon_i^2$$

If N is big enough, this is equivalent to the following equation:

$$v = \frac{1}{\delta}\int_{-\delta/2}^{\delta/2} \varepsilon^2 \partial\varepsilon$$

Then the variance is:,

$$v = \frac{\delta^2}{12} = 0.0833 \cdot \delta^2$$

and the stadard deviation:,

$$s = \frac{\delta}{\sqrt{12}} = 0.29 \cdot \delta$$

2 : Pre launch - CREO results

During WIND software development, CREO m,ade the following analysis.

Sigma nought were simulated using CMOD-1, from wind speed and direction taken from wind fields provided by UK. Met. O. Some noise were added to the Sigma nought. The noise had a standard deviation (Kp) of 9.7 for the Fore and Aft beams, and 8.5 for the Mid beam.

Then, the wind derived by the wind software from the sigma nought were compared with the initial wind field used to simulate the sigma nought.

With a quantisation of 1 m/s for the wind speed, and 1 ° for the wind direction, the standard deviation of the wind speed error and of the wind direction error were respectively of 1 m/s and 6°.

The following tables summarise the results.

Wind speed quantisation	variance due to quantisation	variance due to measure	Total variance	Total standard deviation
0.1	0.0008	1.0	1.00	1.00
0.5	0.0208	1.0	1.01	1.01
1.0	0.0833	1.0	1.08	1.04

Wind direction quantisation	variance due to quantisation	variance due to measure	Total variance	Total standard deviation
1.0	0.0833	36.0	36.08	6.01
5.0	2.0825	36.0	38.08	6.17
10.0	8.3333	36.0	44.33	6.66

3 : Post launch - ERS-1 results

The standard deviation of the errors measured between UK. Met. O. forecasts and ERS-1 scatterometer measurements are respectively 2.0 m/s for the wind speed and 26° for the wind direction.

The variances are respectively 4.0 for the speed and 676 for the direction.

Currently, the quantification used in the WIND software are 0.5 m/s for the wind speed and 10° for the wind direction which introduce a numerical noise with a variance of 0.02 and 8.33 which is negligible.

The high values of the variances measured can probably be related to the resolution differences between the scatterometer and the forecast. furthermore, the forecast misplace the smaller structures which introduce big "errors" of about 180° in certain small areas.