Ocean & Sea Ice SAF

VARIATIONAL AMBIGUITY REMOVAL FOR THE SCATTEROMETER ON-LINE PROCESSING (VARSCAT)

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II.A Introduction

IFREMER's Department of Oceanography from Space has developed specific softwares for on-line and off-line processing of the scatterometer data. It was done by CERSAT under European Space Agency contract. The algorithms resolve well the directional ambiguity problem in nearly 90% of the cases but provides unrealistic wind structures in the 10% left (Quilfen and Bentamy, 1994). These later cases are often linked to energetic mesoscale events that are of great interest for operational meteorology. Taking into account the experience acquired during the ERS experiment and previous studies (Roquet and Ratier, 1988) performed at the French Meteorological Office (METEO-FRANCE), it is proposed to study an algorithm using variational techniques to resolve such cases with a reasonable percentage of success. Variational techniques are used operationally in the meteorological centers to estimate the best fit between the forecast wind field and the available observations (Hoffman, 1984; Courtier, 1993). Thus a strong background exists in this field and can be used for scatterometer data processing.

II.B Pre-existing software

Traditional techniques used at ESA and CERSAT to go from the Normalized Radar Cross Sections (NRCS) to the wind vector are two-step procedures. Different possible wind vectors, up to 4, are first computed for each NRCS measurements triplet by inverting the C-band model. In a second step, the so-called ambiguity removal, a unique wind vector is selected by applying a filter over large portions of the scatterometer swath (called segments, typically of 500 km by 3000 km). Meteo-France has developed an algorithm (hereafter called VARSCAT) finding in one step a unique solution over a segment. It consists in finding the minimum (by variational techniques) of a cost function over the segment. The cost function contains different constraint terms: a term of proximity to the measured NRCS's (in a maximum likelihood sense) and smoothness constraints (wind divergence and curl + others). Some of the minimizing procedures were developed by the "Institut National de Recherche en Informatique Appliquée".

VARSCAT was successfully tested on a few simulated wind cases, using the ERS-1 pre-launched C-band model CMOD2 (Roquet and Ratier, 1988). It is now the basis for the work proposed in the following paragraphs.

II.C Notable differences between the ERS-1 pre-launch hypothesis and the true data.

The azimutal modulation of the backscattering signal is expressed in the C-band model by two terms related to the upwind/downwind and upwind/crosswind asymmetries. These terms strongly depend upon the wind speed and incidence angle. It was shown that they were overestimated by the pre-launched C-band model (CMOD2). Together with the fact that the simulated wind fields used to test the pre-launch algorithm were too smooth, this explains why the ESA and CERSAT operational algorithms occasionally fail to retrieve the wind structures. The VARSCAT algorithm has the advantage that it can use ad hoc physical constraints on the wind field and make use of additional data with great flexibility.

The VARSCAT algorithm has been used as developed by Météo-France at IFREMER for research purposes, mainly to test the numerical aspects (processing time, algorithm convergence...).. It has been shown that the cost function and the software architecture are to be redefined when using true data. This is the basis of the development described here.

II.D Proposed research

The following studies were proposed:

1) The definition of the ad hoc terms of the cost function will be the first step and the following terms will be considered: the smoothness terms, the terms of proximity to the scatterometer measurements, to be defined in the NRCS space or in the wind space, and a term of proximity to other data sources (buoy observations, model analysis).
2) The second important step is to perform sensitivity studies to test whether the method and the different terms weights of the cost function are adequately defined and really active.
3) Extensive tests will be made at IFREMER and a special test set will be defined with KNMI to assess VARSCAT.

II.E Accomplished studies

The different results obtained are presented in the two reports whose references are given below. The Maria Le Ru report describes the method, the tests performed to analyze its numerical behavior and sensitivity, and the results obtained using simulated data and a few real ERS data. The Stoffelen et al report presents the comparison results of different AR schemes using a one month global ERS-2 data set. For that purpose we have adapted the experimental software to run it using the CMOD4 model function (it was developed to work with the CMOD-IFR2 one) and to read the BUFR messages produced at KNMI. We have then produced the one month data-set. The first report shows that the VARSCAT method is internally consistent and robust and that it is a sensible improvement with comparison with the methods operational at CERSAT and ESA. The second report shows that the VARSCAT method compares well with the others and that improvement obtained with the different variational AR schemes (KNMI, DNMI, IFREMER) are not clear by comparison with the PRESCAT algorithm and certainly small. It may indicate that more work is to be done to improve the variational schemes (there is room to improve the VARSCAT one) but also that the way used to compare the different schemes could be improved in order to point out more the differences.

In the paragraph below, we summarize the results presented in the different chapters of the Maria Le Ru report.

- The chapter 1 gives an introduction to the ERS scatterometer instrument and algorithms and describes what is the ambiguity removal problem. It gives also an introduction to the VARSCAT algorithm architecture.

- Chapter 2 is devoted to the cost function description and to explanation of the physical meaning of the different terms.

- Chapter 3 describes the optimization methods used by different inversion softwares (Fletcher-Reeves algorithm, BFGS algorithm).

- In chapter 4 we thoroughly study the cost function anisotropy term. The anisotropy is defined as the normalized difference of the aft and fore beams normalized cross-section. Its behavior is studied as a function of the wind speed and direction. This term is useful in two ways:
  * as a penalty term active in the cost function. Its interest is that it has a great sensitivity to the wind direction.
  * as a validation field after the AR process. Indeed the anisotropy field coherence is very sensitive to errors in the wind direction, and comparison of the measured field with the retrieved one clearly delineates some of the errors.

- In chapter 5, we look at the evolution of the different terms during the process convergence. Two different simulated test cases have been considered: a tropical cyclone and a mid-latitude low pressure system.

- We have determined in chapter 6 an optimal set of weights for the cost function terms. This study uses real data. It is worth to note that the obtained weights depend certainly in some way on the specific data-set used. The validity of the weights for a global data-set is not presented in this document but has been demonstrated to be robust when analyzing the one month processed data-set discussed above. The presented results are limited to the terms active in the first step of the minimization. The same approach has been applied to the others terms.

- In chapter 7, we analyse the sensitivity of the resulting wind field to small perturbations of the weights around the values determined in chapter 6. We apply a methodology defined by Meyer et al. A response function is defined that characterizes the retrieved wind field (a function of the wind divergence and curl). We then can study the robustness of the solution (the wind field) to perturbations of the weights. We evidence a greater sensitivity to the maximum likelihood distance term by comparison with the smoothness term (term not enough active). As anticipated, most of the errors in the retrieved wind field still concern low winds or large gradients in the wind direction.

- Finally, we have compared in chapter 8 the VARSCAT results to the results obtained by the algorithms operational at CERSAT and at ECMWF (PRESCAT), for three different typical and difficult weather cases. All three methods perform well in 95% of the global ERS coverage. These 3 cases are within the 5% difficult cases. The results outline the improvements that can be obtained with the variational ambiguity removal.

To conclude, a new variational ambiguity removal algorithm has been developed, tested and made operational, based on first studies by Météo-France. It provides improvement very sensible when compared with methods operational at CERSAT and ESA but unclear or small when compared with others variational approaches. In the limited allocated time frame for this study, we have not investigated sufficiently some important problems related to such methods. We especially think that there is large room for improvement by choosing a more objective and more physical definition of the weights, and perhaps more important by diminishing the impact of first guess wind field errors (the meteorological forecast) on the retrieved wind field. This is the main limitation of the different variational AR schemes, that could be reduced in VARSCAT since the meteorological winds are used only to initialize the AR process, but not in the process as a proximity constraint as done in others variational schemes.

II.E References

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