THE ADVANCED SCATTEROMETER PROCESSING SYSTEM FOR ERS DATA: THIRTEEN YEARS OF OCEAN WINDS FROM SPACE

R. Crapolicchio*, P. Lecomte**

*Serco S.p.A.
Via Sciadonna 24 00044 Frascati (RM) Italy
Tel: +39 06 942 942 14
E-mail rcrapolicchio@serco.it

**Directorate of Earth Observation – Earth Observation Ground Segment Department
ESA/ESRIN Via G. Galilei 00044 Frascati (RM) Italy
Tel: +39 06 941 80 670 Fax: +39 06 941 80 612
E-mail Pascal.Lecomte@esa.int

Abstract

Since the launch of ERS-1 in 1991 and ERS-2 in 1995, carrying a C-band Scatterometer, a data set of more than thirteen years of backscattered signal from the Earth surface is available for exploitation. With its global coverage, day or night and all-weather operation, ERS Scatterometer data offer unique opportunity for long-term studies and research.

To fulfill the needs of the scientific community, the European Space Agency (ESA) has developed the project: Advanced Scatterometer Processing System (ASPS). Main scope of the project is to provide with state of the art algorithm, high quality and homogenous Scatterometer measurements (sigma nought) of the Earth surface and high quality wind field over the Oceans by re-processing the entire ERS mission. Additional scope is to provide on experimental basis scientific products in high resolution tailored for the emerging Scatterometer application on Ice and Land.

The ASPS project is now in a pre-operational phase and the scope of the paper is to give to the scientific community an overview of the ASPS system. Those new data, available in the next years, hopefully will help the scientific community to better understand and monitor the Earth's climate changes and to protect our environment.

Introduction

The ERS Scatterometer mission initiated in 1991 with the launch of the first satellite and continued in 1995 with the launch of a second satellite is still into operation phase despite some harm occurred on the flight segment. Details regarding the last event happened throughout the mission lifetime are given in a further paper presented in this conference [4].

The basic idea for the Advanced Scatterometer Processing System (ASPS) was born from the initial phase of the ESACA (ERS Scatterometer Attitude Corrected Algorithm) project at the end of 2001 [5]. The re-design of the Scatterometer ground processor was a unique opportunity to have from one side a processor able to operate with the data acquired in Zero Gyro Mode (ZGM) in order to continue the Scatterometer mission and on the other side, to have the core element for a new state-of-the-art facility to re-process thirteen years of ERS Scatterometer data.

Since December 2003 the ASPS system is in a pre-operational phase in ESRIN. Some beta products has been already generated and distributed to some European scientific groups like the ASCAT SAG for evaluation. Scope of this paper is to give an overview of the ASPS system to the scientific and application users worldwide.

The ASPS goals

Beyond the original mission of the ERS Scatterometer, intended to provide measurements of the wind vector over the Oceans, a large number of new unforeseen application have emerged. Originally developed to measure winds over the ocean from space, Scatterometer data has proved to be very useful in a variety of studies. These new applications cover the wind, but also land, continental or sea ice, soil moisture, and vegetation and require high quality and long-term backscatter information.

For those reasons, the first goal of the ASPS is the ERS mission re-processing. The ASPS will provide for conventional and emerging application a homogenous set of measurements of the Earth surface (Land and Ocean) at C-band throughout the different phases of the ERS mission. ASPS will also provide high quality wind fields over the Oceans. This is an important achievement in particular for all applications that need a long and consistent data set of observations like oceanography and climatologic studies. Moreover the quality of the re-processed products will take an advantage from an accurate repetition of the calibration exercise that will be performed before the mission re-processing activity with a new state-of-the-art calibration facility (TOSCA) under development. The scope of that exercise is to compute the best calibration constant and the best characterization of the in flight instrument parameters such as the antenna pattern profile and the calibration sub-system gain for both ERS-1 and ERS-2 instrument.

The second goal is the re-processing of the data acquired during the “Regional Mission” put in place since mid July 2003 to face out the on-board failure of booths tape recorders. In that scenario, the instrument data are acquired in the visibility of several ground stations located in Kiruna (S), Gatineau (C), Prince Albert(C), Maspalomas (Sp), Matera (I), West Freugh (UK) and O’Higgins (Antarctica). In that scenario only a small data segment (ranging between 6 and 12 minutes depending on the station and on the relative orbit) is available in each station for the generation of the fast delivery data. Due to the ERS Scatterometer acquisition geometry a full set of sigma nought triplets are only available for a reduced segment with a drop of about 80 sec at the beginning and end of the acquisition. The ASPS will re-process all those data segment in one go, selecting the best quality raw data from the various ground stations in case of overlaps. An additional improvement to run the processing in one go is the quality of the winds. The algorithm adopted in the ASPS takes care of the wind field coherence within a large area of the swath (about 3000Km along track or 7 minutes of wind data). That condition is not always guaranteed for the single passes currently generated in the ground station.

The third goal is to provide for new applications “scientific” products with an enhancement spatial resolution (25 Km) and Sea Ice detection algorithm.

The fourth goal is the production of a Data Quality report delivered with the ASPS product to the user.

As last achievement, the ASPS shall be able to process ASCAT data (foreseen for launch on Metop on 2005 with 15 years of operations). In that way the ASPS products have the opportunity to cover a three decades of Scatterometer measurements.

ASPS Architectural Design

The ASPS architectural design is presented in Figure 1.

The ingestion modules are responsible for the acquisition of the Instrument raw data packets (echoes, calibration pulse, noise measurements and instrument auxiliary data), the acquisition of the instrument telemetry data (instrument working modes, temperatures, currents and voltages of the transmitter and calibration chain, the antenna temperatures) and the acquisition of the auxiliary data (the state vectors to derive the satellite position and velocity, the correlation time to relate the on-board time with the universal time, the background wind information used to perform the ambiguity removal in the wind retrieval module).

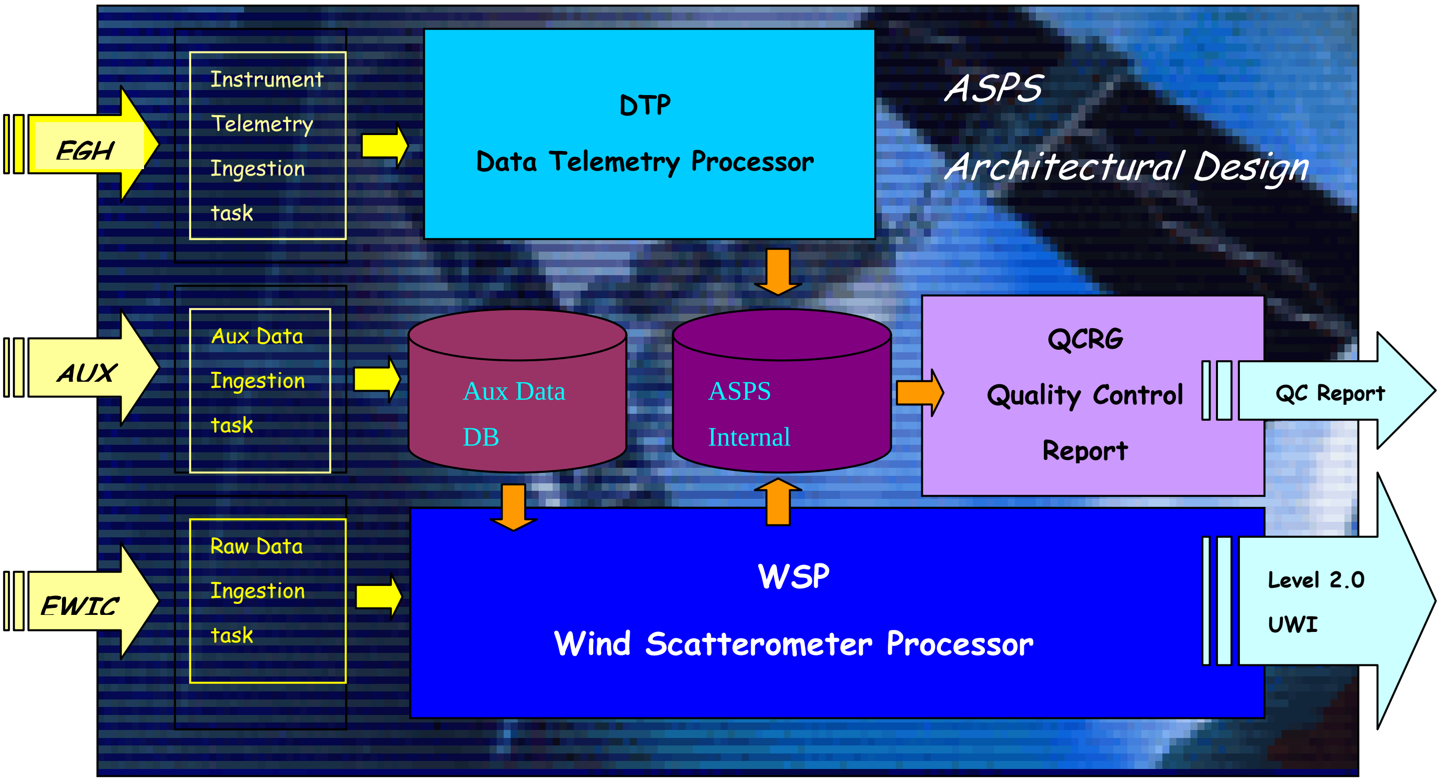

Figure 1 ASPS Design overview

The raw data ingestion task is also responsible to perform a quality analysis of the ingested packets. It is able to patch up corrupted packet or reject low quality packet. In the case that a duplicated packet is available from different acquisition data streams (that is the nominal case for the " Regional mission scenario") the ingestion task is able to select the one with the best quality.

The auxiliary data ingestion task is responsible to store inside an internal database the state vector and the time correlation data. It also responsible to extract from the meteorological forecast the background winds used in the ambiguity removal algorithm and to store that data set in the internal database.

The Telemetry ingestion task is responsible to collect and prepare the instrument telemetry data for the Data Telemetry Processor.

The ASPS main processing modules are:

- The Wind Scatterometer Processor (WSP)
- The Data Telemetry Processor (DTP)
- The Quality Control Report Generator (QCRG)

The WSP is responsible to process the Scatterometer raw data in order to obtain calibrated sigma nought measurements and, over the Ocean, wind speed and direction estimation. It is basically the ESACA processor put into the real time operation since June 2003 with some upgrades concerning the ingestion of the raw data and the detection of the arcing event in the transmission tube. The detail description of the ESACA processing chain is reported in reference [7], here are described the main advantages of this new processor with reference to the old processing chain named LRDPF.

- The LRDPF processor was based on a large number of pre-computed off-line parameters (Look Up Table) interpolated throughout the processing while the ESACA computes exactly all the data on the fly.
- ESACA contains the yaw estimation module to process data acquired in ZGM.
- The computation of the sigma nought is performed only if at least 50% of the spatial filter is filled with valid samples.
- The computation of the radiometric resolution (Kp) has been refined with a more accurate algorithm to estimate the real variance present in the echo samples.
- The wind retrieval is performed with the CMOD-5 geophysical model function developed by ECMWF [3].
- The ambiguity removal scheme has been upgraded with the Modified Successive Correction (MSC) algorithm developed by DNMI [10].
- Generation of an intermediate product for Quality Control (QC) and instrument long loop assessment (ASPS Level 1.5) and a new user product (ASPS Level 2.0).
- Generation of a scientific Level 2.0 product with high-resolution sigma nought (25 Km) and Sea Ice detection flag based on neural network output [8].
- Processing of ASCAT data

The DTP is responsible for the extraction of the instrument working modes timelines and the computation of the averaging values (per orbit) of the following instrument parameters:

- Input and output calibration sub-system power
- TWT Currents and Voltages

- TWT and Antenna Temperatures

Those parameters are stored in the ASPS internal database for further processing.

The QCRG is responsible for the generation of a report containing data quality and long-loop instrument performances information. The report is an output product of the ASPS and its content is mainly based on the parameter monitoring during the ERS mission lifetime [2], [9]. The scope of the report is to give to the user a good level of confidence on the data. The report contains the following information derived from the ASPS internal database and from the ASPS Level 1.5 and Level 2.0 products.

A time-series with the evolution (averaged over one orbit) of the following parameters: the CoG of the received signal spectrum, the CoG of the Doppler compensated received signal and its standard deviation, the yaw error angle, the internal calibration level, the noise power, the number of nodes affected by arc, the number of 3 valid sigma noughts, statistics on the various PCDs contained in the Level 1.5 and Level 2.0, the distance from the C-Band model, the antenna profiles computed over the Brazilian rain forest, the histograms of the gamma nought over the rain forest, the evolution of the peak position of the gamma nought histograms, the evolution of all the instrument telemetry parameters as extracted by the DTP module, the log of the Out Of Limit values (Yaw, Doppler, Calibration power, Noise) that affects the data quality, the log list of the missing data.

The ASPS Products

The Table 2 reports an overview of the products generated by ASPS. The standard ASPS product available for the users is the Level 2.0. The Level 2.0 scientific will be available on request and only for specific orbits. The UWI product will be also generated on request. The Level 1.5 is an engineering product and is not available for the end users. A detailed description of the Level 2.0 product is available on http://earth.esa.int/pcs/ers/scatt/reports/articles/. The "historical" UWI product is described in [6]. A preliminary presentation and discussion of the ASPS products performances is given in [1].

Table2 ASPS Products Overview

Product Name	Description	Size [Mb]
ASPS Level 1.5	The Product is structured as: MPH, SPH, DSR The SPH contains averaged values for instrument long loop monitoring (Doppler frequency, Calibration energy, Noise power, Yaw error angle) and processing monitoring. The DSR contains Intermediate-processing parameters. Each DSR contains information from one Fore-Mid-Aft (FMA) sequence therefore the sampling is about one DSR per second. The product covers one orbit from ascending node crossing. The total number of DSR is, for a full orbit, about 6000	Full Orbit 0.5 MB
ASPS Level 2.0	The Product is structured as: MPH, SPH, DSR The SPH contains averaged values for data QC (statistics on the PCD flags at node level, mean wind speed and direction biases, mean distance to the CMOD model) and processing information. The DSR contains one row of across track node (19 nodes). The main parameters of the node are the following (see Table4 for details): • 3 beam sigma nought • Rank 1-4 Wind Vector • Ambiguity removed Wind Vector • Sea/Land Flag • Yaw angle flag The geometrical resolution of the node is about 50x50 Km^2 the distance between two adjacent nodes is constant and equal to about 25 Km. The sampling of the DSR (along track) is about 25 Km. The product covers one orbit from ascending node crossing. The total number of DSR is, for a full orbit, about 1500	Full Orbit 2.7 MB
ASPS Level 2.0 Scientific	As the Level 2.0 but • 41 nodes across track • Node resolution about 25 Km distance between two adjacent nodes about 12.5 Km • DSR sampling along track about 12.5 Km • Sea Ice flag	Full orbit 11.5 MB
	The Product is structured as: MPH, SPH, DSR The SPH processing information. The DSR contains one square of 361 nodes (19x19). The main parameters of	

UWI	the node are the following (see [9] for details): • 3 beam sigma nought • Ambiguity removed Wind Vector • Sea/Land Flag • Combined Kp/Yaw flag The geometrical resolution of the node is about 50x50 Km^2 the distance between two adjacent nodes is constant and equal to about 25 Km (along track and across track). One UWI covers an area of about 500x500 Km^2 One full orbit correspond to about 83 UWI products	Full orbit 1.5 MB

An overview of the ASPS Level 2.0 Product

The *Main Product Header* is valid for all ASPS products and it is as the one used in the fast delivery data (UWI). It contains information regarding the quality of the acquisition chain, the data acquisition time, the processing time, the auxiliary data (state vector and correlation time) and the software version used. A detailed description is given in [9]. The *Specific Product Header* (SPH) contains information regarding the processing performed: nominal or high resolution, the type of window applied for the spatial filter, the distance to the CMOD used to retrieve the wind, the algorithm used for the wind retrieval: fast or precise. In the first case a table is used to describe the CMOD geophysical function, in the second case is used the analytical formula of the CMOD. The SPH stores statistics on the various flags associated with the nodes as an indicator of the product quality. In the SPH are also stored: the mean wind speed and direction biases (Scatterometer winds vs Meteorological background winds) and the mean distance to the CBAND model. The *Data Set Record* contains one row of across track nodes. The number of nodes is 19 for the nominal resolution and 41 for the high-resolution product. The information at the node level is an upgrade of the one contained in the UWI product. The philosophy behind was on one side to keep as much possible a “well known and historical” format in order to make possible an easy use of the product and on the other side the ZGM operation phase adds some specific parameters that have been taken into account. One example is the node acquisition time with reference to the antenna (Fore, Mid Aft) that is not present in the UWI. Those fields allow a direct correlation of the node with the instrument raw data (the echoes) and instrument telemetry as well as the correlation with the Level 1.5 product. That because in the ZGM phase, the yaw angle is evolving (up to some degrees) along the orbit and for that reason the acquisition geometry is not fixed as for the nominal Yaw Steering Mode (YSM). This fact is causing the lost of a constant relationship between the acquisition time of the echo and the position of the samples on the Earth surface. In order to keep the position of the nodes on a fixed grid (independently from the yaw angle) the ground processor assign a position on the Earth surface to all the samples and then collect the ones that contribute to the node. As consequence the acquisition time for the Mid beam samples cannot be solely used to derive the corresponding acquisition time of the Fore and Aft antenna samples that are contributing to the node. For that reason three different times are provided for the same node. A further example in the Level 2.0 is the enlargement of the Product Confidence Data (PCD). The PCD section-1 (field 39) contains new information regarding the "Spectral properties" of the sample used to build the node. The aim of those PCD is to monitor the signal spectrum as received from the instrument (bits 12-14) and at the end (bits 6-11) of the ground processing. The effect of a yaw error angle in the received spectrum is to frequency shift the signal. Taking into account that the on-board receiver has a limited bandwidth (about 30 KHz) the signal shift cannot exceed a fraction of that value without the lost of the energy. The bits 12-14 are set if the frequency shift is above a configurable threshold. Once the yaw angle is estimated by the Doppler shift, is it possible to compensate the spectrum for that value. The bits 6–11 summaries the quality of the received spectrum after the on-ground Doppler compensation. An effective compensation provides a spectrum with a relative narrow bandwidth centered on the low pass filter shape. In that case the best signal to noise ratio is achieved with an accurate measurement of the backscattered energy. Examples of additional information for the application users are the field from 24 to 38. Those fields report the 4 wind solutions as derived by the wind retrieval algorithm. The wind solution (speed and direction) is ranked with reference to the Euclidian distance between the measured triplets and the CMOD. The value of the Maximum Likelihood Distance is also reported for each sea node. In field 36 and field 38 is reported the wind speed and direction bias. It is the difference between the Scatterometer wind (the one selected by the ambiguity removal) and the meteorological wind used as background in the ambiguity removal.

Conclusion

The purpose of this paper is to introduce the ASPS system to the scientific and application users. Further technical details are given in the references, most of them

available on the ESRIN-PCS web site: http://earth.esa.int/pcs/ers/scatt/reports/articles/
Some ASPS beta products are available from the authors for evaluation.

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