Data Quality Control applied on ESA and Third Party Missions within the frame of IDEAS

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ABSTRACT

The Instrument Data quality Evaluation and Analysis Service (IDEAS) provides operational quality control for ESA satellite missions such as ERS, ENVISAT, Earth Explorers, and some selected ESA Third Party Missions like Landsat or MODIS. The IDEAS team works in close collaboration with different ESA entities, external scientific groups and industrial partners in order to accomplish the quality objectives.

The quality monitoring task is an on-going activity, which is continuously improving, with the purpose to ensure that all quality requirements are met. The goal is to provide users with the best quality of data during near real-time processing of the mission and on mission reprocessed data sets. The information generated by IDEAS is accessible to users for example via routinely produced reports that also contain important information related to calibration and validation activities.

In this paper we show the principles of the IDEAS Quality Control activities, using a particular example of the ERS-1 and ERS-2 Scatterometer full mission reprocessing which is ongoing to provide a consistent and quality assured long-term dataset covering 20 years.

Keywords: IDEAS, ERS, ENVISAT, Quality Control, Data Archive

INTRODUCTION

The importance of long-term, continuous, and homogenous time-series of satellite data is widely accepted within the international scientific community. The effort towards a reliable and up-to-date archive has been, in fact, continuously increasing in the last years, and, as result of this, various global projects and initiatives have been undertaken (as the Long Term Data Preservation Working Group [1], the Permanent Access to the Records of Science in Europe (PARSE) [2], or the Global Climate Observing System (GCOS) [3]).

All the aforementioned projects agree about the importance of the data quality assessment, in terms of reliability of the data itself, but also of preservation of the "knowledge" associated to the data (as the processing algorithm, the calibration and validation assessment, etc…).
In this paper, an example of an existing and operative quality control and configuration tracking procedure is presented: the European Remote-sensing Satellite (ERS)-1 and ERS-2 Scatterometer quality monitoring, performed by the Instrument Data quality Evaluation and Analysis Service (IDEAS). The main outcome of this activity can be found at [4] and is summarized in this paper.
The paper is structured as follows: IDEAS is presented in the first section; A brief introduction to the ERS-2 Scatterometer is included in second section; The third and fourth sections are devoted to the quality control and data validation activities, respectively; The reprocessing activities are described in the fifth section, and, finally the main conclusions are explained in the last section.

IDEAS (INSTRUMENT DATA QUALITY EVALUATION AND ANALYSIS SERVICE)

IDEAS (Instrument Data Quality Evaluation and Analysis Service) is a consortium of several European companies led by Vega UK that performs the operational Quality Control on behalf of ESA for satellite missions as ERS, ENVISAT, Earth Explorers like Cryosat-2, and some selected ESA Third Party Missions like Landsat or MODIS.
The Quality Control activities include operational data calibration and monitoring, instrument performance assessment, verification and maintenance of the Instrument Processor Facility (IPF) in the Ground Segment (GS).
The QC team works in close collaboration with the following teams:

- The QWG (Quality Working Groups) is a consortium of research groups and laboratories that is in charge of the definition of the scientific baseline to be applied for the operational processor
- The ESL (Engineer Support Laboratory) translates the scientific inputs of the QWG in an engineered software (the prototype) used as reference for developing the IPF
- The Ground Segment (GS) team is responsible for the operational data acquisition, processing and dissemination to the users community
- The Validation teams provide the independent measurements to be used for the scientific validation of the operational products
- The PLSO (Post Launch Support Office at ESTEC) is responsible for monitoring the overall satellite equipments (service modules and payloads), and for the global performance evolution (e.g.: mission extension)
- The FOC (Flight Operations Center at ESOC) is in charge of the satellite in-flight operations
- The science community is the end-user of the data, but it is also part of the QC and validation process, since the scientific inputs are often important in order to tune the data quality assessment

The tasks performed by the IDEAS consortium will be explained by presenting an example: the European Remote-sensing Satellite (ERS) scatterometer data quality monitoring. This is presented in the next sections.

THE INSTRUMENT

The ERS-1 [5] and ERS-2 [6] satellites were launched by the European Space Agency (ESA) in 1991 and 1995, respectively. The last was decommissioned on July 7, 2011, after more than 15 years of acquisitions, 20 if considered jointly with ERS-1. On-board instrumentation is very similar for ERS-1 and ERS-2, these both embarks a Radar Altimeter working in the Ku-band (13.8 GHz), the Along Track Scanning Radiometer (ATSR) (infra-red and microwave), a microwave radiometer (acquiring at 23.8 and 36.5GHz), a synthetic aperture radar, and a wind scatterometer, both measuring at 5.3 GHz. In addition to that ERS-2 also has an ultraviolet and visible spectrometer called Global Ozone Monitoring Experiment (GOME).

The ERS wind scatterometer [7] consists of three different antennas looking at 45° forward, sideways, and 45° afterward with respect to the satellite's flight direction. The resulting swath is 500-km wide and is centered 450 km at the right of the satellite’s nadir; the nominal spatial resolution of the ERS-1/2 wind scatterometer is 50 km, each resolved point at the Earth is called node. The scatterometer measures the so-called radar cross-section σ^0 of the Earth surface, which is, on the sea, directly connected to the sea roughness, in turn coupled with the surface wind speed (it increases when the wind speed increases).

Since their launch, both ERS-1 and ERS-2 passed through a number of changes of the acquisition configuration, part of those were intentional modifications aimed at improving the performance, but in several occasion those were caused by instrument failures or degradation. A summarizing sketch of the configuration tracking for ERS-2 is shown in Fig. 1 as an example.

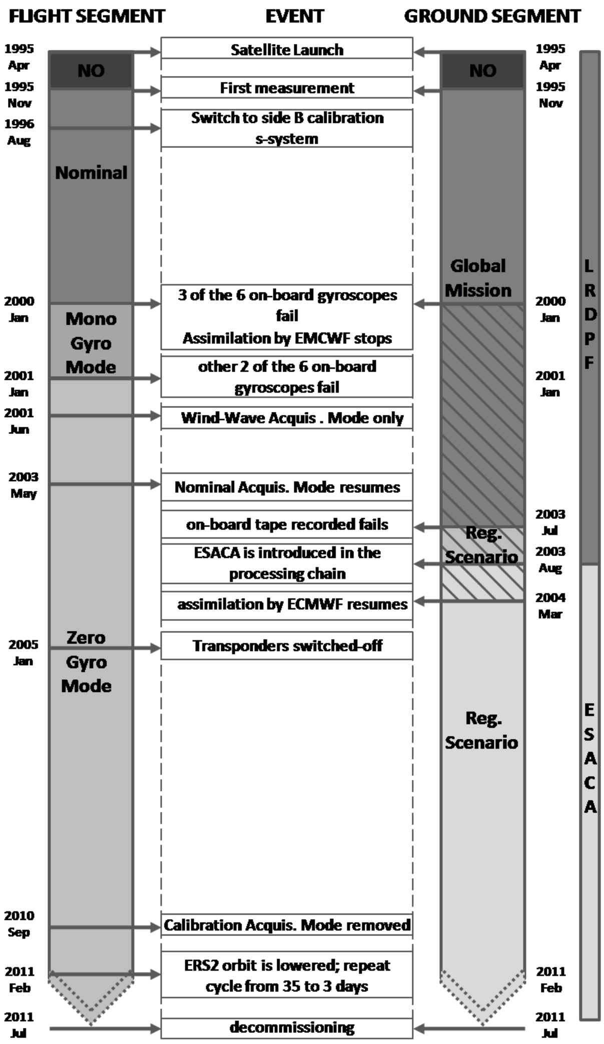


Fig. 1 (between the time-bars) Main events that affected ERS-2 satellite, and their effects on (left time-bar) flight and (right time-bar) ground segment. The small bar on the extreme right shows the change in data processor at the ground segment.

QUALITY CONTROL

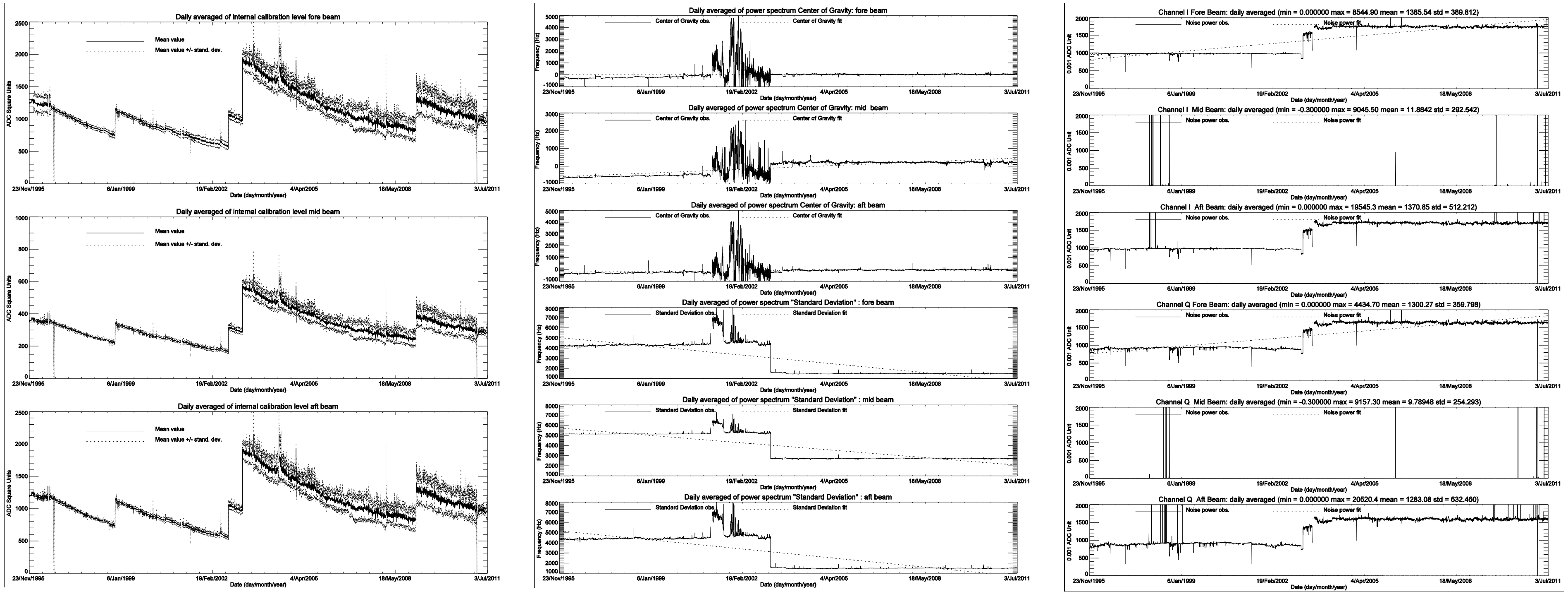
Three key parameters have been selected to monitor the ERS scatterometer long loop performance, namely the *internal calibration pulse power*, the received signal spectrum (in terms of *Centre of Gravity (CoG) and its standard deviation*), and *noise power for both the I and Q channels*. These are briefly described hereafter, and more extensively commented in the technical report released on a quasi-monthly (every 35 days) basis by IDEAS, and freely available at [4].

Internal calibration pulse power: The transmit pulse is produced at the Intermediate Frequency, amplified, up-converted to Radio Frequency, and amplified again by the High Power Amplifier (HPA) before being routed towards the antennas. The path for the received pulse is contrary, with the received echo routed to the low noise amplifier of the receiver. The internal calibration pulse power is a replica of the transmitted pulse injected into the receiver by the calibration sub-system. It is used to calibrate the received echo and is regularly monitored to assess the performance of both the transmitter and receiver chains.

Centre of Gravity (CoG) and its standard deviation: Due to the relative motion between the satellite and the target, the radar echo emitted by the Earth surface does not have the same frequency for all the observed nodes. This frequency shift is much larger for the side antennas (50 – 150 kHz) than for the Mid one (±10 kHz). To compensate for that shift, satellite yaw is continuously modified as well as the central frequency of the scatterometer receiver. The receiver signal spectrum Centre of Gravity (CoG) and its standard deviation monitor the orbit stability and the performances of the Doppler compensation filter (on-board and on-ground compensation).

Noise power for both Q and I channels: Any received echo is affected by noise, and this must be subtracted to obtain the noise-free backscatter. Noise power on both Q and I channels is constantly recorded and sent to the ground stations for the correction.

In Fig. 2, an example of the three variables is shown, for the Fore, Mid and Aft antennas since the beginning of ERS-2 scatterometer operations in November 1995 and until its decommissioning in July 2011. Figure 2 (a), (b), and (c) are the daily (solid line) averaged value and (dashed line) standard deviation of the internal calibration power, center of gravity, and noise power for both the *I* and *Q* channels, respectively.



(a) (b) (c)

Fig. 2 Daily (solid line) averaged value and (dashed line) standard deviation of the (a) internal calibration power, (b) center of gravity, and (c) noise power for both the *I* and *Q* channels, for the Fore, Mid and Aft antennas since the beginning of ERS-2 scatterometer operations in November 1995 and until its decommissioning in July 2011.

Figures are not commented because considered out of the scope of this paper, more detail can be found at [4] and [8].

In addition to the nominal monitoring, since 2003, the stability of the satellite is also routinely checked by IDEAS. During the nominal mode and the Mono-Gyro Mode (until January 2001), the stability of the satellite attitude was assured by the 6 (3 during the Mono-Gyro Mode) on-board gyroscopes. Since January 2001, and until August 2003, between the entrance in the Zero-Gyro Mode and the introduction of ERS Scatterometer Attitude Corrected Algorithm (ESACA) in the processing chain (Fig. 1), satellite attitude was not guaranteed. ESACA processor, analyzing the spectrum of the received echo, computes the error on the yaw angle estimation and compensate for that the final calibrated σ^0, it also generates a dedicated product (the HElpful Yaw, HEY, product), which is regularly recorded; the different steps of the satellite yaw monitoring are shown in Fig. 3.

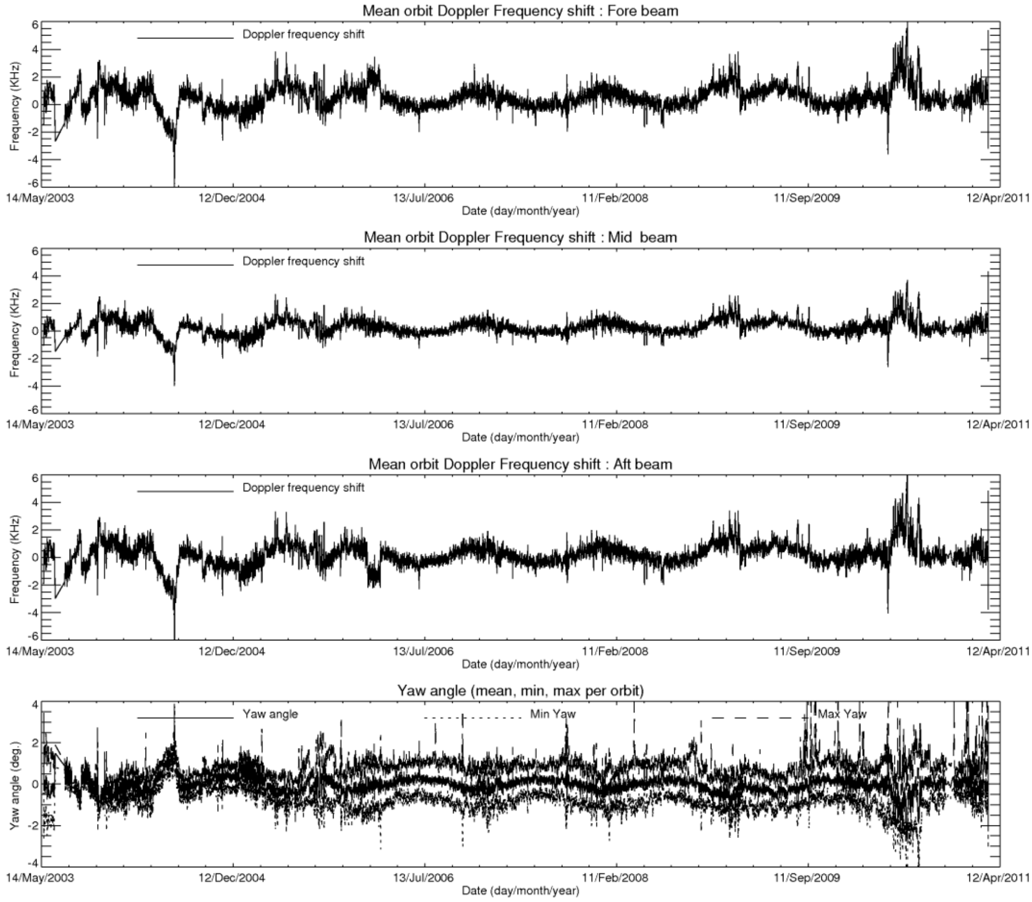


Fig. 3 Satellite's yaw monitoring.

The result of the monitoring (fourth plot) is a yaw error angle within -/+ 2 deg. for most of the orbits. That value is within the specification for the ESACA processor to assure calibrated data.

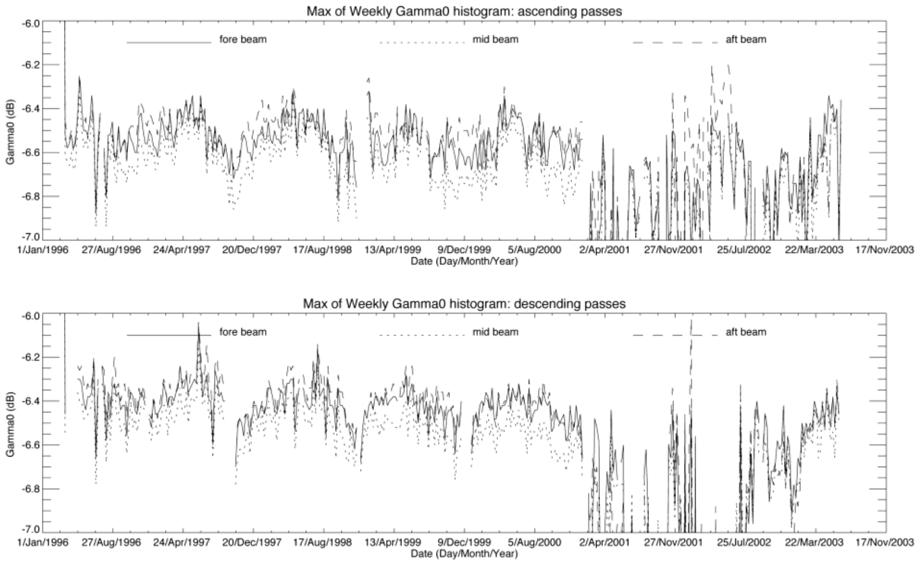
DATA VALIDATION

Data, as acquired by the satellite, are continuously validated by using reference targets, with known electromagnetic characteristics, or by comparison with model predictions. Examples for both the techniques are presented in the following paragraphs.

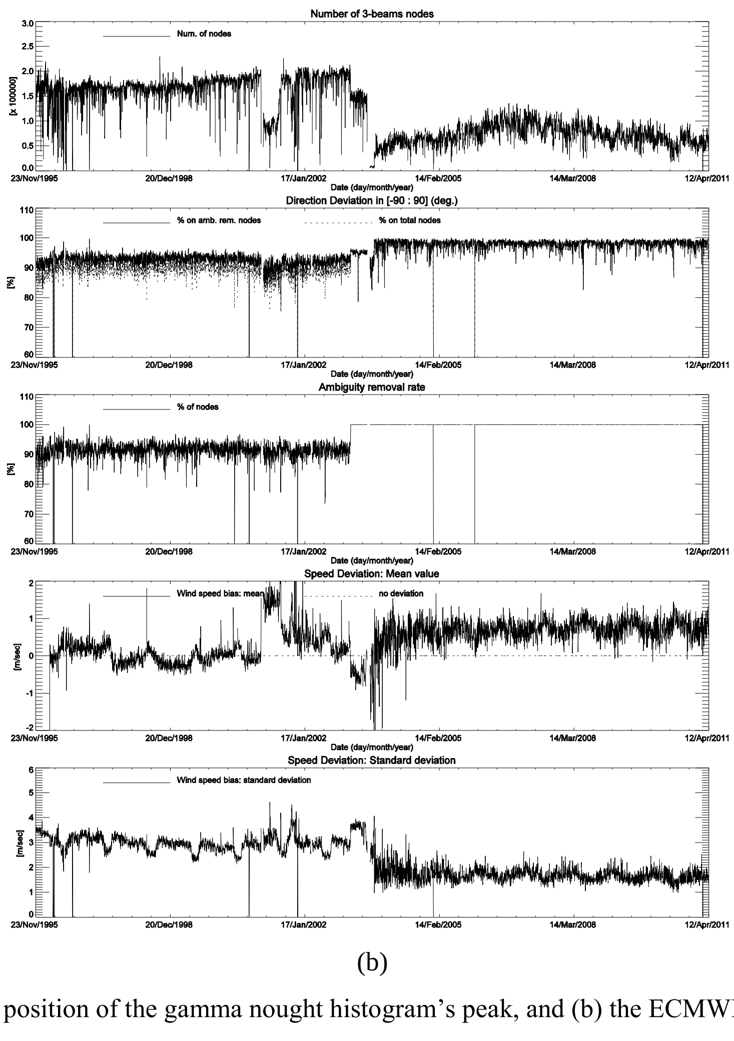
Reference targets – The case of the Rain Forest: To monitor the instrument calibration and validate the antenna pattern of the ERS scatterometer, the tropical rain forest in South America has been used as a reference distributed target by the Product Control Service. Rain forest acts, at the C-band, as a very rough surface, the transmitted signal can be assumed to be equally scattered in all directions. Under this assumption, the measured backscattering is depending only on the area observed by the instrument. This purely geometrical dependence can be removed by normalizing the σ^0 with the cosine of the incidence angle (γ^0).Histograms of γ^0 are weekly computed by the PCS.

Comparison with models: The quality of the wind products delivered to the end-users is monitored by IDEAS in tight collaboration with the European Centre for Medium-Range Weather Forecasts (ECMWF). Quality analysis is performed daily.

In Fig. 4, (a) the position of the γ^0 histogram's peak, and (b) the ECMWF comparison are shown; the first from the beginning of the mission (November 1995) until the failure of the recording tape (July 2003), and the second one until the decommissioning of the satellite (July 2011).



(a)



(b)

Fig. 4 (a) the position of the gamma nought histogram's peak, and (b) the ECMWF comparison.

As for Fig. 2 and 3, no further comments are included in this paper about the results of the data validation. More information can be found at [4] and [8].

REPROCESSING ACTIVITIES

With the objective of creating a homogeneous, high-radiometric-quality, and high-resolution wind speed and direction databases, the reprocessing of both the ERS-1 and ERS-2 campaigns has been planned, and it is being performed since July 2007.

- The main objectives of the ASPS project are:
- Reprocess Zero Gyro Mode data acquired between 2001 and 2003.
- Reprocess the data acquired in the so-called “Regional Mission Scenario” (Fig. 1).
- Reprocess ERS-1 data, so to build a homogeneous database involving both satellites.
- Provide yaw correction information.
- Enhance the spatial resolution. With the improved algorithm the return signal is processed to provide backscattering coefficients (and all the geophysical parameters derived) with the nominal spatial resolution of 50 km, but also with an enhanced resolution of 25 km.
- Finally, provide a detailed QC report to monitor the instrument performances and the data quality.

Several improvement are included in the reprocessing, among them: a more accurate antenna pattern characterization, a more precise forward model, a more effective ambiguity removal algorithm, a better yaw angle estimation.

Currently, a total of 60 cycles (22 – 81, from May 1997 to May 2003) of ERS-2 have been reprocessed. Each reprocessed ASPS data cycle has been submitted to a quality control procedure aimed to verify the completeness of the time series, the correct instrument parameters, the data quality, and the proper processing. Reprocessed cycles are available on the web at [9].

CONCLUSIONS

The particular case of ERS-2 scatterometer has been shown as example of effective and operative quality control and processing configuration tracking. The ERS-2 scatterometer data quality and the instrument performance have been monitored on a daily basis since its launch in 1995. This information was regularly reported on the ESA ERS web site at [7] and [10], and played a fundamental role in the definition of the reprocessing activities.

Both the routine analysis and the documentation of the results through periodic technical report, containing long term trend information of the data quality, have demonstrated to be an important contribution to the monitoring and improvement of the accuracy and reliability of the data. The lessons learnt during such a long period (20 years) of ERS scatterometer data quality analysis will be very useful for the definition of future archiving protocols and quality assessment procedures. The data set resulting from the full mission reprocessing with the applied quality control in context with the Long Term data Preservation project at ESA, will allow that the end users have not only access to a unique data set but also full visibility of the related quality information.

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