New I-PAF Products and Services

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Abstract

This paper presents the new ERS Multiband and Interferometric products developed at the Italian Processing and Archiving Facility (I-PAF, Matera) as support to the users processing activities and applications development.
The Multiband product (ERS.SAR.MBP) consists of a set of two or more ERS images registered by an Automatic Registration System. This product is distributed in HTML format that includes the raster data for each band, a quick look of the images, the registration parameters and the most useful annotations.
The Interferometric Products are ERS.SAR.SRI (Single look complex Registered Image) and ERS.SAR.WFI (Wavenumber shift Filtered Image). The first product is a multiband image obtained registering two or more Single Look Complex (ERS.SAR.SLC) products. The final data consists of a set of annotated complex images.
The ERS.SAR.WFI product is a multilayer product, derived by the ERS.SAR.SRI. It containins the complex and filtered interferogram, the coherence map and the interferogram flattened on the earth ellipsoid.
Also the interferometric products are released in HTML format.

Keywords: ERS, SAR, products, interferometry, I-PAF, multiband.

Introduction

The Italian Processing and Archiving Facility (I-PAF) located at the Space Geodesy Center "G. Colombo" in Matera is one of the four ERS facilities devoted to archive and distribute ESA standard products relevant to the Mediterranean regions.
These products have a large user community, either in the field of image processing or in applications and environmental monitoring. Moreover the complexity of the processing and the analysis of the data make the SAR remote sensing a tool for expert users only.
In the last year, new ERS non standard products have been defined in order to improve an extensive use of ERS data and to provide a support to non expert users interested in the exploration and developments of SAR remote sensing applications. These new products are the multiband and the interferometric products.

Multiband Products

For many of the ERS applications, such as land use classification or change detection, a single image often doesn't provide exauustive information. Therefore is necessary to register more than one image acquired in different times on the same geographic area.
In order to perform the registration a reference image *(master)* is selected and the other ones *(slaves)* must be registered so that for each pixel the values of all the bands can be available. This is performed by mean of a warp function that describes the correspondence between the master and the slaves pixels. This function is obtained on the basis of some Ground Control Points (GCPs) selected on the master and for which the corresponding coordinates on the slaves are well known. This function is often a polynomial function of various degree, depending on the type of distortion present on the images (Richards-1986 , AA.VV-1993 , Pratt W.-1991). Usually the GCPs are manually selected by operators, but this operation is often very imprecise and time consuming.

ERS.SAR.MBP (MultiBand Product)

The multiband product, also called multitemporal product, is a new service of the Italian PAF for the users interested in the comparison of many images acquired on the same geographical area. This product consists of a set of two or more ERS images (e.g. a set of PRI) that are registered together, producing as output a multilayers image.

The registration process is performed by an Automatic Registration System that only requires as input the image to be considered as master, the number of GCPs to collect, the warp degree and the interpolation type. This tool automatically selects the Ground Control Points to be used in the warp function definition, evaluating the images cross-correlation due to similarity in their morphology.

The automatic selection is performed in two main steps: GCPs prediction and GCPs refinement.

The GCP prediction is performed on the basis of the correspondence between the master and the slaves. It is obtained starting from the geographical coordinates of the four corners and on the basis of a projection model of the image on the earth ellipsoid (Graf-1988 *et al.*). Then, an equally spaced grid of GCP is generated on the master image and, for each point, the geographic coordinates and the corresponding slave images coordinates are computed.

A further GCP position refinement is performed estimating the peak of the bidimensional cross correlation between the master and the slave, extracted in a cell around the point. The algorithm is optimized by mean of an interpolation step, based on FFT and zero pad (Oppenheim-1983 *et al.* , Burrus-1984 *et al.*). Both the cell size and the interpolation factor are selectable.

The goodness of the GCPs can be tested correlating again them and verifying that the shift is zero. The GCPs that do not met this condition (e.g. sea points) are rejected. The remaing ones are used to derive a warp function. The points having a residual respect to the warp function greater than a threshold value are excluded too. Finally the slave image is resampled on the basis of the warp function. The interpolation algorithms available are: nearest neighbours, bilinear interpolation and cubic convolution.

All the above operations are repeated for each slave image.

The multiband product (Figure1) is distributed in a new HTML format that includes all the most important CEOS annotation, both the quick look of the multiband product and of each single band, the registration parameters and the raster data for each band. Each annotation is has a hyperlinked description of the parameters.

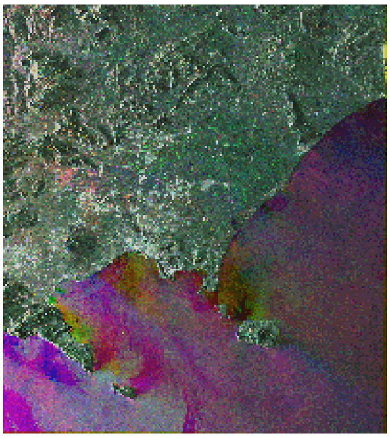

Figure1. Multiband products on Naples. This product is obtained by registering three ERS-1.SAR. PRI acquired in different times.

Interferometric Products

The ERS Interferometric Products are ERS.SAR.SRI (Single look complex Registered Image) and ERS.SAR.WFI (Wavenumber shift Filtered Image). The first product (Single look complex Registered Image) contains a couple of registered complex images with some new annotations like the baseline value for every image line. The final data consists of a set of annotated complex images.

The second product (Wavenumber shift Filtered Image), derived by the SRI, contains the following layers: complex and filtered interferogram, coherence map and interferogram flattened on the earth ellipsoid. The input data for the Image Registration step is a couple of complex products (e.g. ERS.SAR.SLC), in slant range/azimuth coordinate system, given as an IQ data sequence with each channel quantized in signed 16 bit format. The key point in the SLC registration is the derivation of the warp function that is obtained by using orbital and geographical information, image morphology and coherence maximization.

ERS.SAR.SRI (Single look complex Registered Image)

As for the Multiband Product, a very coarse registration between the master and the slave is automatically performed on a regular GCP grid, starting from the image geographic location and orbit. Then the system extracts a set of master-slave cells, calculates the cross correlation and interpolates to reach a 0.1 - 0.5 pixel precision. The fine GCPs collection uses the Coherence Maximization algorithm to find a high precision shift. The warping function is then derived with the same steps implemented for the multiband product. A filter of the GCPs is made considering the coherence mean value and standard deviation, computed in a cell around the points. The next operation consists in the slave interpolation. Due to the dimensions of the images (e.g. 2500*15000 for a quarter of scene) the slave SLC is segmented into small blocks of selectable size. The interpolator function has to be carefully selected because of the different characteristics in range and azimuth of an SLC. Infact, in the azimuth direction the warp function shows small variation but the spectra is not zero centered and so no "simple" low pass interpolator can be used. In the range direction the spectra are zero centered but the variations of the warp function is high. For these reasons the interpolation is performed first along azimuth and next along range direction. Along the azimuth, for each column of the input block the mean shift is computed and applied using a FFT method. Along the range, a cubic convolution interpolation is performed. As last step, a coarse baseline computation is done, based on the propagated orbits and on the warp function. Using the warp it is possible to synchronize the time of the two orbits and to evaluate the baseline as vector function of the master line, expressed in a three dimensional Conventional Terrestrial System (CTS). In the ERS.SAR.SRI product the coefficients of the 1st degree polynomial fitting each component of the baseline vector are annotated .

ERS.SAR.WFI (Wavenumber shift Filtered Interferogram)

The presence of a terrain slope seen in slight different way by the master and the slave image produces a shift in the range spectra of the interferometric couple (Prati *et al.* , 1993 , Gatelli *et al.* , 1994). This effect, called Wavenumber shift has to be taken into account to avoid the interferogram decorrelation associated to the geometry. In order to correct this decorrelation effect, a filtering of both the images must be done, with a couple of "wavenumber" filters. These filters are generated starting from the knowledge of the local interferogram fringe frequency (related to the local terrain slope). In the first step, a subdivision of the SRI data is done, with cells equally spatiated.. The sampling is done using sharp features because the frequency shift has a strict dependency from the slope change in the imaged terrain zone. For each cell, the relative frequency shift is estimated deriving a local range fringe frequency map. The two "wavenumber" filters, distinct for the master and slave image, are then generated as range and azimuth dependent functions and a standard method (like Overlap and Save) is used to filter the entire SRI data. It is worth to say that, before the filtering, the images are interpolated in range by two, using a FFT and zero pad, to avoid the aliasing effect during the interferogram formation step. The resulting output product is called WFI - (Wavenumber effect Filtered Images) and consists of a wavenumber effect filtered master-slave couple. From the previous WFI couple the complex interferogram is simply obtained multiplying the master WFI with the conjugate of the slave WFI. This leads to a complex image which has as amplitude the product of the master and slave amplitude, and as phase the phase difference between the two images. The coherence map can be evaluated as usual provided that the topographic factor are corrected, as given from the local 2D fringe frequency, and using "non biased" coherence estimation algorithms (Touzi *et al.* , 1996 , Cattabeni *et al.* , 1994) . In such way the coherence map is derived and given as a further layer of the WFI data. In Figure 2 the histogram of coherence image on Etna is reported.

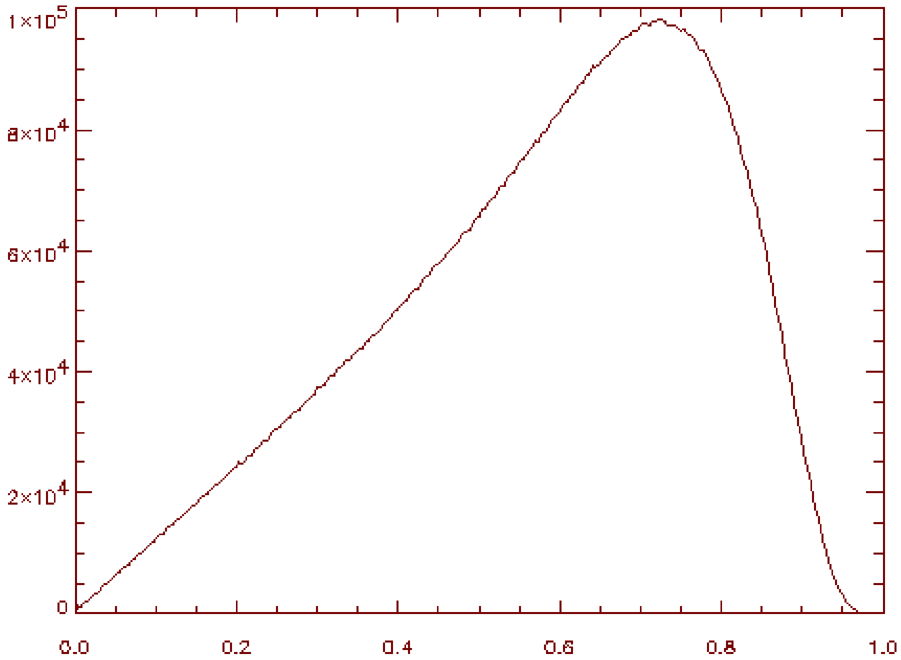

Figure2. Histogram of coherence image.

Given a certain geometry of a couple of side looking SAR sensors, only one half of the fringe frequencies has a physical meaning. The other half comes from the noise and the layover effect. The geometry determines which is the right half spectrum and so the sign of the layover filter. Once this filter is evaluated, the complex interferogram can be filtered giving in output another layer of the WFI product, the filtered complex interferogram. Using the baseline, the orbital data and the earth ellipsoid shape, the phase contribution which depends by the presence of a "mean terrain" can be computed. The subtraction of this effect from the interferogram is called flat terrain correction. After this step, the interferogram fringes depends only on the elevation above the ellipsoid. An example of this product is reported in Figure 3. The last step is the phase unwrapping of the interferogram, which recovers the true phase from its residual modulus 2 PI. At present many algorithms exist, each with advantages and drawbacks (Just *et al.* , 1995). For this reason we are actually analyzing the various approaches, to find the best solution to the unwrapping problem for an operational context.

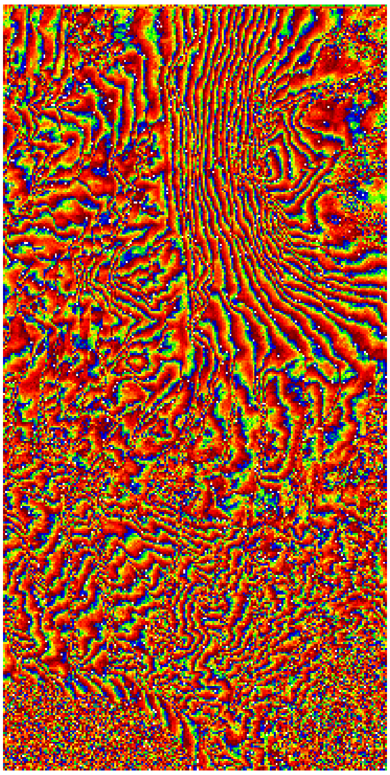

Figure3. WFI phase with flat terrain correction.

Conclusions

A first description of the I-PAF Multiband and Interferometric products is given. The products are under validation and they will be soon available to the users as experimental products. The SAR user community will take advantages from the availability of new general purpose products of certified and reliable quality.

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