ASAR multi-swath techniques

Andreas Wiesmann, Urs Wegmüller, Charles Werner and Tazio Strozzi
Gamma Remote Sensing, Thunstrasse 130, 3074 Muri BE, Switzerland
Tel: +41 31 9517005, Fax: +41 31 9517008, e -mail: wegmuller@gamma-rs.ch

***Abstract*—In 2002 ENVISAT with the advanced SAR (ASAR) as one important instrument was launched. As compared to the preceding SARs on ERS-1 and ERS-2 the ASAR has additional functionality with many different modes. Important aspects of the ASAR include the alternating polarization modes for quasi simultaneous acquisition of data at two different polarizations, and beam-steering capability, which permits to acquire data at different incidence angles. To optimize the use of the new functionality adequate processing techniques are required. This is particularly important for data acquired in different swaths, i.e. with different image geometries. In this paper ASAR multi-swath techniques are discussed, including image co-registration, multi-channel filtering, and multi-swath multi-temporal techniques.**

Keywords-component: ENVISAT ASAR; multi-swath; image registration; multi-channel filtering; temporal variability.

I. INTRODUCTION

Over the last 12 years applications of space-borne SAR have become more and more mature. The good availability of SAR data of consistently high quality for over a decade from ERS satellites was a very important element for this development. In 2002 the follow-on sensor ASAR on ENVISAT was successfully launched. While the sensors on ERS-1 and ERS-2 were single mode SARs ASAR can be operated in many different modes with relevant additional functionality including beam-steering, multi incidence angles and multi-polarization. It can be expected that this flexibility will improve the potential for many applications. In addition, new applications may evolve, for example by exploiting the polarization and incidence angle dependence of the backscattering coefficient. But this increased functionality also requires the processing techniques have to be adapted, especially when combining data acquired in different swaths.

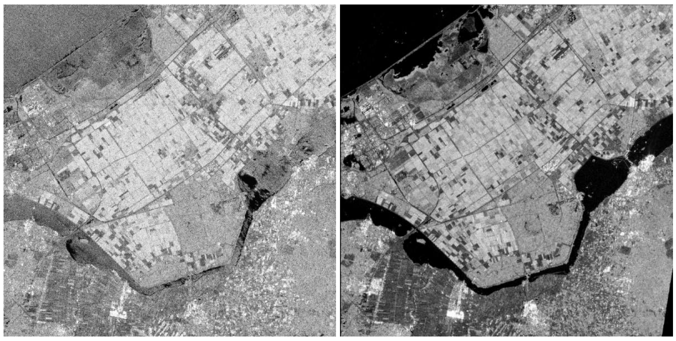
The objective of this contribution is to present and discuss ASAR multi-swath techniques and concepts for multi-polarization and multi incidence angle data. Important issues include geometric aspects, radiometric aspects, multi-channel filtering and the estimation of combined features such as polarization ratios.

II. MULTI-SWATH DATA CO-REGISTRATION

For a combined interpretation of multiple images the most common method is to co-register all the images to the same geometry. In the case of rather flat surfaces this may be done through the co-registration of ground-range images by using control points. For the more general case of terrain with significant height differences the recommended approach is to apply terrain corrected geocoding for both scenes, with a fine-registration step to adjust the transformation for one of the images so that the geocoded images match as good as possible [1,2]. The registration accuracy is affected by errors in the considered reference heights which transform into position errors in the across-track direction. Table I gives an overview of the across-track position to height error sensitivity for the different ASAR swaths. The registration error corresponds to the difference between the two across-track position errors for images acquired from the same side, i.e. both in ascending orbit or both in descending orbit, and to the sum of the two across-track position errors for images acquired from opposite sides approximately. Height errors are most critical for the registration accuracy at low incidence angles. Even the use of a relatively poor DEM as a global DEM is often significantly better than no compensation of height *distortions* at all.

TABLE I: ACROSS-TRACK POSITION TO HEIGHT ERROR SENSITIVITY, $\Delta x / \Delta h$, OF THE ASAR SWATHS.

ASAR Swath	Reference incidence angle [deg.]	$\Delta x / \Delta h$ [m/m]
IS1	18.0	3.08
IS2	22.0	2.48
IS3	28.0	1.88
IS4	33.0	1.54
IS5	37.0	1.33
IS6	40.0	1.19
IS7	43.5	1.05



ASAR IS2 VV, 15-Nov-2002 ASAR IS7 VV, 22-Nov-2002

Figure 1: Flevoland, co-registered multi-incidence angle ASAR data in transverse Mercator projection. Area size is 32 km x 32 km.

An example for co-registered ASAR IS2 and ASAR IS7 data is shown in Figure 1. A sub-pixel registration accuracy with offset standard deviations of 2.5 *m* in Easting direction and 1.7 *m* in Northing direction was achieved in this case.

The same procedure can also be used to co-register data acquired in dual azimuth pass combination, i.e. data acquired in ascending orbits with data in descending orbit.

III. MULTI-CHANNEL FILTERING

With multiple images available over the same area multi-channel filtering similar to [3] can be used to reduce the signal noise. This applies to multi-polarization, multi-swath, as well as multi-temporal data. The main aim of this process is to create a set of *M* speckle-reduced images by linearly combining *M* registered images acquired on the same area. The filter function is [5]:

$$J_i = \frac{\sigma_i}{M} \sum_{j=1}^{M} \frac{I_j}{\sigma_j} \qquad 1 \le i \le M \tag{2}$$

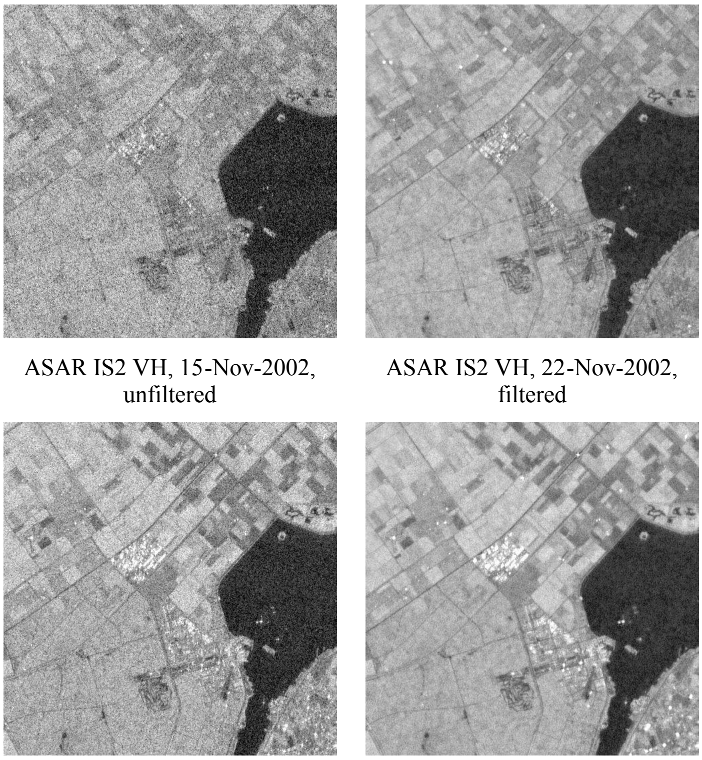
where J_k are the filtered output data, I_i are the input intensity data and σ_i is the estimate of the local mean backscattering coefficient. σ_i is estimated from the data by averaging intensity values in a local window around each pixel in each image. One possibility is to use an adaptive estimator for σ_i to optimize the trade-off between good reliability of the local estimate and little spatial degradation.

TABLE II: ASAR DATA USED

Track	Orbit	Date	Mode	Polarization
Asc.	03590	06-Nov-02	IS2	HH
Asc.	03590	06-Nov-02	IS2	HV
Desc.	03712	15-Nov-02	IS2	VV
Desc.	03712	15-Nov-02	IS2	VH
Desc.	03812	22-Nov-02	IS7	VV
Desc.	03812	22-Nov-02	IS7	VH

TABLE III: ESTIMATION OF EQUIVALENT NUMBER OF LOOKS (ENL) FOR HOMOGENEOUS WATER AREAS BEFORE AND AFTER THE MULTI-CHANNEL FILTERING.

Orbit	Date	Mode-Pol.	ENL	
			unfiltered	filtered
03590	06-Nov-02	IS2-HH	3.0	15.7
03590	06-Nov-02	IS2-HV	2.9	15.8
03712	15-Nov-02	IS2-VV	2.8	15.0
03712	15-Nov-02	IS2-VH	2.8	15.3
03812	22-Nov-02	IS7-VV	5.4	18.7
03812	22-Nov-02	IS7-VH	4.6	18.0



ASAR IS2 VH, 15-Nov-2002, unfiltered

ASAR IS2 VH, 22-Nov-2002, filtered

ASAR IS7 VV, 22-Nov-2002, unfiltered

ASAR IS7 VV, 22-Nov-2002, filtered

Figure 2: Flevoland, ASAR data before and after multi-channel filtering. Area size is 10 km x 10 km. The data used for the filtering are listed in Table 2, ENL estimates before and after filtering in Table 3.

The multi-channel filtering was applied to a set of 6 ASAR images of quite different modes as listed in Table II. All the images were co-registered and then multi-channel filtering was applied using all 6 images and a Frost filter to estimate the spatial averages. For two images small sections of the filtered and unfiltered images are shown in Figure 2. For homogeneous water areas the equivalent number of looks (ENL) was determined for the unfiltered and filtered images, using the methods of moments:

$$ENL = (mean / stdev)^2 . \tag{3}$$

The results (see Table III) confirm the very significant speckle reduction which was achieved by the multi-channel filtering. The reason for the higher ENL for the unfiltered images acquired in IS7 mode is the higher ground-range resolution which results from the higher incidence angle. The gain in ENL on the other hand is higher for the IS2 mode images as they particularly benefit from the lower noise IS7 mode data.

IV. MULTI-SWATH MULTI-TEMPORAL DATA

As was previously shown for ERS the backscatter temporal variability has a good potential to separate classes with low temporal backscatter variability as forest and urban from classes with high temporal backscatter variability as fields and water [4-6]. Figure 3 shows the multi-temporal variability calculated for 8 ERS scenes acquired in repeat-orbits. For

ASAR data similar multi-temporal data in a single swath can be acquired. There is an interest to extend the concept of multi-temporal data as a source of information to multi-channel data which may include ASAR data acquired at different incidence angles (swaths) and polarizations. This becomes more complex though for two reasons. The first one is that the backscattering coefficient changes with incidence angle and polarization and the second one is that this dependence is different for different surface classes.

An approach to map forest may be to scale the different scenes relative to the backscattering of forest. This was done in Figure 4 using 6 ASAR scenes acquired at different incidence angles and polarizations. For the large majority of agricultural fields the relative ASAR temporal variability is significantly higher than the temporal variability of the ERS scenes. The different incidence angle and polarization dependence of the fields as compared to forest as additional source of variability is the explanation. In this example the relative temporal variability describes the similarity of the signatures to the signatures of forest. Of course other reference classes could be selected. Or as a more general approach the similarity of sequences could be identified and used for classification purposes. This can be done either using a supervised approach with training areas or using an unsupervised approach. In the unsupervised approach similar sequences are identified as the same class, but without labeling the class at the same time.

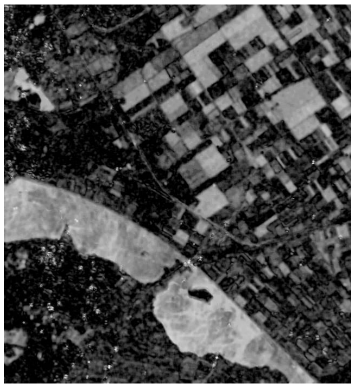


Figure 3: ERS multi-temporal variability calculated from 8 scenes acquired in repeat orbits.

Figure 4: ASAR multi-channel relative variability of 6 scenes acquired at different incidence angles and polarizations.

V. CONCLUSIONS

Processing techniques required for investigation of ASAR data acquired in different swaths were presented. The validity of these techniques was confirmed with first data examples. To precisely co-register data acquired in different geometries we recommend to use terrain corrected geocoding of each image to a map projection. In our implementation the geocoding transformation is refined using automatic matching techniques which permits to achieve sub-pixel co-registration accuracy if an accurate DEM is used. For cases without high resolution DEM available we recommend to use a global DEM, as the registration accuracy is significantly better with a course DEM than without DEM.

Multi-channel filtering is highly recommended to reduce image speckle. The example shown confirmed the applicability of this technique for data acquired with different incidence angles and polarizations.

Being exited about new possibilities offered by multi-polarization and multi-incidence angle data the multi-temporal aspect of the data should not be left aside. This is of course much more challenging for data acquired at different incidence angles because of the target specific incidence angle dependence. An approach to estimate a measure similar to the temporal variability was presented.

VI. ACKNOWLEDGMENT

This work was supported by ESA contract 17011/03/NL/JA and by the Bundesamt für Bildung und Wissenschaft, Switzerland, as part of their support to the ENVISAT Cal/Val Project 210. ASAR and ERS SAR data © ESA.

VII. REFERENCES

[1] Werner C., T. Strozzi, U. Wegmüller, and A. Wiesmann, SAR geocoding and multi-source image registration, Procs. IGARSS'02, Toronto, Canada, 2002.

[2] U. Wegmüller, T. Strozzi, A. Wiesmann, and C. Werner, Envisat ASAR for land cover information, Procs. IGARSS'03, Toulouse, France, 2003.

[3] Quegan and Yu, Filtering of multichannel SAR images, IEEE Trans Geosci. and Remote Sensing, vol. 39, no. 11, 2001.

[4] LeToan, T., S. Quegan, M. Davidson, J.M. Martinez: Radar remote sensing of forests. Applications using existing satellite SAR data.- Proc. 8th Int. Symp. Physical measurements and Signatures in Remote Sensing, Aussois, pp 33-40, 2001.

[5] Quegan S., Le Toan T., Yu J.J., Ribbes F., Floury N., Multitemporal ERS analysis applied to forest mapping, IEEE Trans. Geosci. and Remote Sensing, vol. 38, no.2, pp. 741-753, 2000.

[6] Wegmüller U., A. Wiesmann, T. Strozzi, and C. Werner, Forest mapping with multi-temporal SAR, Proc. ForestSAT'02 Conf. Edinburgh, Scotland, 5.-9. Aug. 2002.