K&C Science Report – Phase 1
Generation of PALSAR mosaics over Africa and Eurasia

Gianfranco De Grandi and Ake Rosenqvist
European Commission Joint Research Centre, Inst. for Environmment and Sustainability
Global Environment Monitoring Unit, TP. 440, 210 27 Ispra (VA), Italy
frank.de-grandi@jrc.it & ake.rosenqvist@jrc.it

Francesco Holecz and Stefano Monaco
sarmap – Cascine di Barico, 6989 Purasca, Switzerland
fholecz@sarmap.ch & stefano.monaco@sarmap.ch

***Abstract*—The JRC contribution to the Kyoto & Carbon Initiative constitutes the continuation of the collaboration with JAXA (then NASDA) which started more than 13 years ago within the framework of the Global Rain Forest and Boreal Forest Mapping (GRFM/GBFM) projects. The JRC is here responsible for the generation of 50 m resolution ortho-rectified PALSAR mosaics over the African continent (on-going) and subsequently, over Siberia and Europe, for the year 2007. The data used are the slant range path data processed by JAXA EORC, each some 1000~2000 km in length. Comprehensive calibration procedures have been developed to cope with the radiometric and geometric characteristics of the path image data.**

All data were acquired as a part of the systematic observation strategy implemented by JAXA for ALOS PALSAR, which is designed to provide consistent wall-to-wall coverage of all land areas twice pers year during the mission life of ALOS [1]. 319 path images were used for the generation of the Africa mosaic, out of which 276 of the passes were acquired during the main time window of June-August, 2007, another 27 passes during the next 46-day cysle (Sept-Oct, 2007), while 16 passes (i.e. 5% of the total) had to be filled in from the 2008 acquisitions.

***Index Terms*—Africa, ALOS PALSAR, K&C Initiative, Mosaic Theme.**

I. PROJECT STATUS

A. Development of methods and software tools for the generation of K&C ALOS PALSAR mosaics.

Analysis of the problems related to processing high volumes of K&C FBD dual polarization strip data has been carried out and resulted in the implementation of an automatic processing chain (see below). This effort sets the stage for the implementation of all the remaining subtasks, which is currently under way. However, please notice that improvements and refinements of methods and software code will be possibly undertaken in the extension phase if required in the course of further experiments or developments. As it always happens in science and technology, the word "completed" should be taken with due care. From this standpoint, it is proposed that the code will be delivered to JAXA only when duly consolidated. In any event the current version of the code will be included in the K&C final report for phase 2006-2008.

This task addresses the theoretical and operational requirements for the assemblage of the K&C continental scale radar mosaics. The target is the generation of geo-coded terrain corrected continental scale imagery with high radiometric quality - supporting consequently the generation of thematic products. This goal and the high data volume associated with the mosaics' generation calls in turn for the development of a bespoke and highly automated processing chain. Accordingly, a major effort has been undertaken for designing algorithms and developing software that could meet the K&C requirements. By now, a fully automatic processing chain for K&C mosaicking is in place and under test in the generation of prototype Africa radar mosaics. The processing chain consists of a blending of bespoke IDL modules and functional components supplied by SARSCAPE, a commercially available radar processing software developed by SARMAP s.a, Switzerland. The main modules and the operation flow are:

- House keeping routines to handle the ingestion and file structure of the JAXA strip data.
- Adaptive calibration revision of the original slant range data sets. This module automatically checks for the presence of radiometric anomalies (power loss in range) and calibrates accordingly the data.
- Extraction from a global Africa digital elevation model of subsets corresponding to the geographical extent of each strip data. The global Africa DEM was generated by the Consortium for Spatial Information (CGIAR-CSI). It is based on Shuttle Topographic

Mission data (SRTM) and missing data were filled using interpolation and auxiliary topographic data.

- Generation of batch files for importing calibrated JAXA strip data and SRTM tiles into SARSCAPE.
- Geo-coding into a geographic reference frame (un-projected latitude-longitude for Africa) using the solution of the range-Doppler equations (as implemented in SARSCAPE). This step also produces auxiliary data holding the effective local incidence angles for each pixel of backscatter data.
- Compression of the geo-coded data sets.
- Mosaicking of the compressed geo-coded strips within a geographic bounding box and using inter-strips blending.
- The whole process is repeated for data acquired at HH and HV polarizations, resulting finally in a co-registered set of 3 layer mosaics (backscatter HH, HV and local incidence angle).

B. Developing methodology for forest change and land cover mapping.

Methods for forest structural parameters estimation from K&C imagery have been extensively investigated both from the theoretical and experimental stand-points. However full scale application of the methods to arrive at the generation of thematic products as required by subtasks 1.d will be possible only when the final version of the mosaics will be available. This task will therefore be completed in the extension phase.

C. Developing methodology for product validation and accuracy estimation.

Classical methods were used for estimating the geometric accuracy of the geo-coded products. These methods call for tie-pointing with reference imagery (e.g. Landsat) of known accuracy. Radiometric calibration assessment is based on the assumption that slant range detected products delivered by JAXA are already nominally calibrated for range power spreading loss and effective scattering area. Radiometric checks are only performed in cases where calibration anomalies are detected (e.g. power loss in range) and consist of supervised profiling of selected areas featuring homogeneous distributed targets (e.g. forest).

D. Generation of K&C PALSAR mosaics and related products.

Two factors have delayed the task progress: i) some outliers in the PALSAR data acquisition plan, which made full coverage of the areas interest complete only later and by gap-filling acquisitions; ii) technical complexities related to the new PALSAR data sets and the target specifications of the products to generate. In our opinion, both aspects are typical of large scale projects and almost unavoidable when straddling into new terrain, as it is a case in point with the K&C continental scale mosaics. Moreover, notice that the project plan and priorities have been changed with respect to what originally stated in the JAXA-JRC agreement. This was due, on the one hand, to a change of priorities in the JRC research programs (focus shifted from Boreal towards Tropical regions) and to the other hand, to a reschedule of the overall commitments of the K&C science team. Basically, the generation of the whole Africa mosaic, not initially foreseen, has now been taken over by JRC, while the generation of the Boreal area mosaic and the related thematic products has been postponed. This point will be further elaborated in section 2.1, because it is instrumental for the definition of tasks in the requested extension phase. Major difficulties encountered in processing PALSAR data in connection with the assemblage of K&C mosaics were:

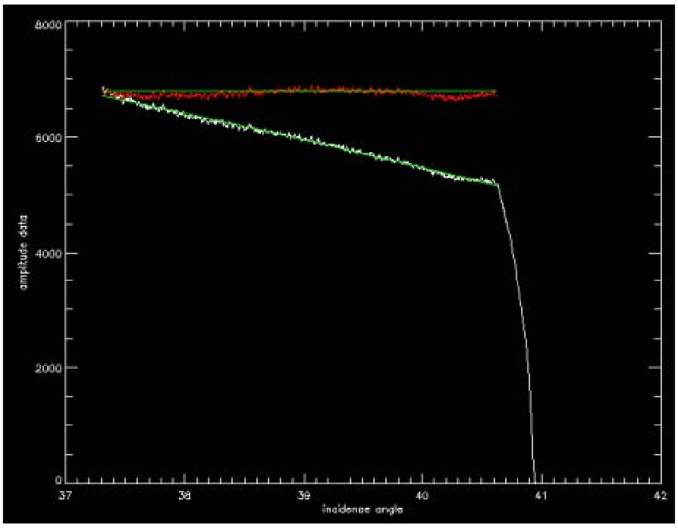


Figure 1. Example of range power loss flaw in K&C strip data, and correction by automatic flaw detection and a range-dependent empirical function

a) SAR focusing (JAXA SigmaSAR processor) in non-zero Doppler geometry. As a consequence the geo-coding algorithm, based on the solution of the range-Doppler equations, had to be redesigned.

b) Missing information on Doppler centroid estimation in some early data acquisitions. JAXA supplied code to retrofit the data.

c) Range power loss anomalies in some data sets (Fig. 1)

d) Computational problems related to the high volume of data. This problem stems from the intrinsic large coverage character of the mosaics, but also from the geometry of the long K&C SigmaSAR strip data. The raster representation of this type of imagery, once projected into a geographic reference frame (viz. geo-coded), tend to be quite inefficient, due to the large number of non significant data elements (e.g. pixels outside the imaged area). These features have an impact both on external and internal memory allocation, and on processing time. The problem has been partially alleviated by introducing a simple compression algorithm, after the geo-coding step. The mosaicking procedure then de-compresses on the fly the data sets before pasting into external memory

At the time of this writing, several prototype mosaics over Africa have been assembled. The scope of this experiments is to debug and validate the processing chain, in particular with respect to assuring a seamless assemblage of the strips, a fact that depends both on proper geometric and radiometric

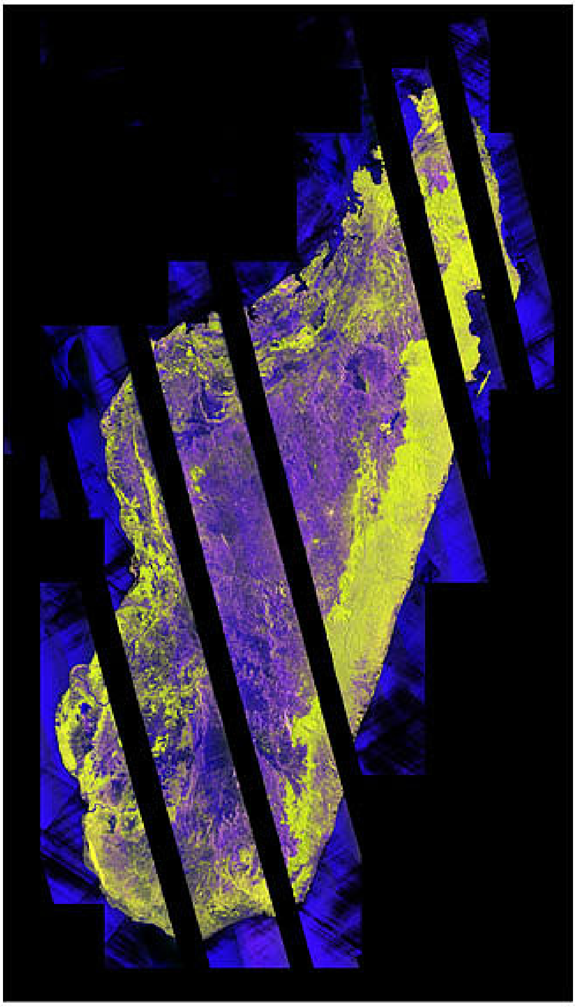


Figure 2. Prototype K&C mosaic over Madagascar.
Processed by JRC © JAXA/METI

fidelity. An inter-strip blending algorithm assures a good visual perception of the mosaic, even in the presence of residual mismatches, due for instance to temporal changes, or local incidence angle effects. Some examples are reported in Fig. 2 and 3. Processing of a prototype full Africa mosaic is scheduled to be completed by end 2008. The generation of the Europe and Siberia mosaic will have to be shifted to the requested extension phase. Additional difficulties in the generation of this mosaic stem from the unavailability of a homogeneous digital elevation model (DEM). Indeed the SRTM derived DEM covers only up to 60 N in latitude. Work is in progress to generate a global DEM over Siberia by blending SRTM and GTOPO DEMs. Notice finally that an additional product, not originally foreseen by the agreement, has been developed in the K&C context by the JRC: a full coverage of Venezuela at 200 m resolution using PALSAR data in SCANSAR mode. This product is intended as a test bed to prove the capability of the K&C processing chain with respect to SCANSAR acquisition mode, and to support a specific JRC commitment towards the European Commission's delegation in Venezuela.

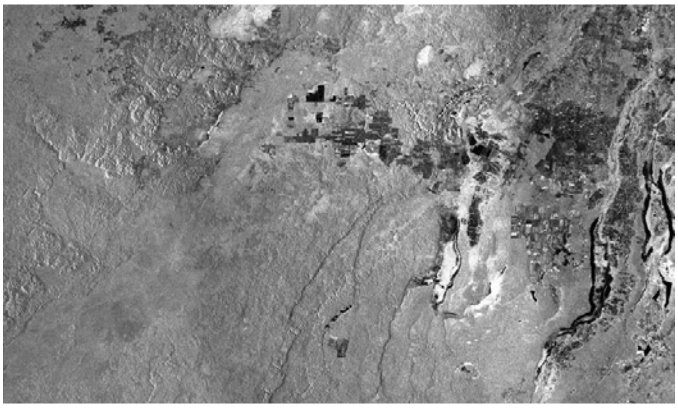


Figure 3. Subset of a prototype Africa K&C mosaic at full resolution, showing the seamless assemblage of two strips. © JAXA/METI

II. PLANS FOR PHASE 2

A. Completion of work from Phase 1

The major driving forces that caused a change in the original planning have been discussed above and can be summarized as follows:

- Complexity of the end-to-end project path, from data acquisition to generation of final products. This aspect touches upon both partners, JAXA and JRC.

- Steering of research focus at JRC from Boreal to Tropical areas and in particular to Africa. The consequences, as far as the K&C first phase is concerned, were:

1. Decision by JRC to take up the task for the generation of the whole Africa mosaic (not foreseen in the original agreement).

2. Priority allocation of resources to solving methodological and computational problems related to this product, with consequent phasing out of other commitments originally listed at point 1.2.4.

3. Delay in the task completion

Given this scenario the JRC tasks were amended to bridge over to the extension phase in a way that would still assure the delivery of comparable "value" to JAXA in terms of products and methods:

Task E1: Final version of the dual-polarization mosaic over the whole African continent. The mosaic will complemented by auxiliary data sets, such as the corresponding DEM, local incidence angle information, and a set of ground control point to document the geometric accuracy (notice that a prototype mosaic will be delivered still within phase one). Foreseen end time: April 2009.

Task E2: Compilation of the Europe-Siberia mosaic, and auxiliary data sets (e.g. dual-resolution DEM). Foreseen end time: December 2009.

Task E3: Thematic products concerning land cover mapping in Africa.

- Study of the transition zones at the border of the Congo basin, with emphasis of deforestation patterns, re-growth, forest fragmentation, embedded savannah (as detailed in the original work plan). Foreseen end time: December 2010.
- Update of the GRFM Central Africa wetlands map.
- Regional scale forest resource assessment and estimation of forest cover change with respect to years 1997 (GRFM acquisitions) in Central and West tropical Africa. Foreseen end time: Dec 2010

Task E4: Research and development of methods for forest structural and bio-physical parameters retrieval using fusion of K&C radar mosaics, orbital earth observations in the optical domain, orbital LIDARs, and topographic information. The study will be conducted using test cases in the tropical and sub-tropical domains. It will be an extension of work carried out in task 1.2.2 of phase 1 (see paper [2]). It will be conducted in collaboration with the department of geography, University of Wales at Aberystwyth. Foreseen end time: Dec 2011

ACKNOWLEDGEMENTS

This work has been undertaken within the framework of the JAXA Kyoto & Carbon Initiative. ALOS PALSAR data have been provided by JAXA EORC.

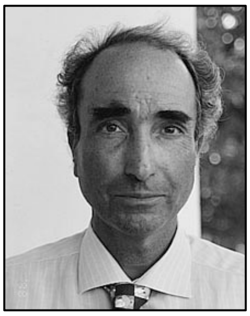
REFERENCES

[1] Rosenqvist A., Shimada M., Ito N. and Watanabe M. “ALOS PALSAR: A pathfinder mission for global-scale monitoring of the environment,” *IEEE Trans. Geosci. Remote Sens, vol. 45, no. 11, pp. 3307-3316, 2007.*

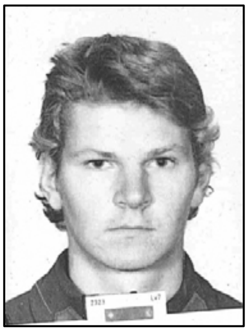
[2] G.. De Grandi, R.M. Lucas, J. Kropacek," Analysis by Wavelet Frames of Spatial Statistics in SAR Data for Characterizing Structural Properties of Forests", IEEE Trans. on Geoscience and Remote Sensing, vol. 47, issue 2, 2008, in press.

[3] G. De Grandi, J. Kropácêk, T. L. Ainsworth, "Spatial Properties of Forest Clutter in Polarimetric SAR Imagery Measured by Wavelet Frames", Proc. 5th International Symposium on Retrieval of Bio- and Geophysical Parameters from SAR Data for Land Applications, Bari, 2007.

[4] G. De Grandi, J. Kropacek, A. Gambardella, M. Migliaccio, T. Ainsworth, "Analysis of Spatial Statistics in Polarimetric SAR Data Using Wavelet Signatures", Proc. EUSAR08, 2008.



Gianfranco (Frank) De Grandi (M’90–SM’96) received the Ph.D. in physics engineering (with honors) from the Politecnico Milano, Milano, Italy, in 1973. Since 1977, he has been with the European Commission Joint Research Centre (JRC), Ispra, Italy, where he has performed research in signal processing for application areas such as gamma ray spectroscopy, data communications, and radar remote sensing. In 1985, he was a Visiting Scientist with Bell Communications Research, Morristown, NJ, where he participated in the design of METROCORE, one of the first research projects for Gb rate metropolitan area networks. From 1986 to 1989, he headed the signal processing section of the Electronics Division, JRC, where he introduced VLSI design technology and conducted research, in cooperation with Bellcore, on packet video, and in cooperation with ITALTEL Italy on the European digital mobile phone network. In 1989, he joined the Institute for Remote Sensing Applications [now Space Applications Institute (SAI)], where he started a research activity in radar polarimetry in the Advanced Techniques unit. Since 1994, he has been Principal Scientist for radar remote sensing in the Global Vegetation Monitoring unit. Since 1997, he has been Assistant Professor with the Faculte’ de Foresterie et Geomatique, Universite’ Laval, Quebec, PQ, Canada. His current research interests span a wide gamut, including global scale forest mapping using high resolution spaceborne SAR, multiresolution analyses based on the wavelet representation for texture measures, backscattering multitemporal estimators, topography sensing using polarimetric SAR data, and the statistics of polarimetric synthesized SAR images. Dr. De Grandi is a senior member of the IEEE Geoscience and Remote Sensing and Signal Processing Societies and a member of the Planetary Society, Pasadena, CA



Ake Rosenqvist is Science Coordinator for the Kyoto & Carbon Initiative. He is presently a Marie Curie Fellow with the EC Joint Research Centre in Ispra, Italy, and part of the TREES group at the Global Environment Monitoring Unit. His research interests include forest- and wetlands monitoring and support to climate change science and policy needs. With a background from the Swedish Space Corporation, where he was involved in land cover and topographical mapping with SPOT, he deserted the optical field in 1993 and spent 9 years illuminated by radar at the Japanese Space Agency, JAXA/NASDA. He has been involved in the development of the JERS-1 and ALOS applications programmes, the establishment of the JERS-1 Global Forest Mapping (GRFM/GBFM) and ALOS K&C Initiative projects, and the design and implementation of systematic data observations strategies adopted by JAXA for the ALOS mission.