

An overview of the JERS-1 SAR Global Boreal Forest Mapping (GBFM) project

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Abstract - Boreal ecosystems play an essential role in global climate regulation. Forests constitute pools of terrestrial carbon and are generally considered as global sinks of atmospheric CO₂, contributing to attenuating the greenhouse effect. Large amounts of carbon are also stored in boreal lakes, bogs and wetlands, partially released as CH₄ and other trace gases to the atmosphere during the spring and summer months. Human activities in the forest zone are however reducing the size of the carbon pool and climate change is triggering shorter winters and earlier thaw onset, changing the natural equilibrium. Given its global importance, there is a need to map and monitor the boreal zone, and as the changes occur on all from local, regional to global scales, fine resolution information over vast areas is required.

The Global Boreal Forest Mapping (GBFM) project is an international collaborative undertaking initiated by NASDA in 1996, as a follow-on to the tropical-focused Global Rain Forest Mapping (GRFM) project [1]. Utilising the L-band Synthetic Aperture Radar (SAR) on the Japanese Earth Resources Satellite (JERS-1), one of the main objectives of the GBFM project is the generation of extensive, pan-boreal, SAR image mosaics, to provide snap-shots of the forest-, wetland and open water status in the mid-1990's. Mosaics over Canada, Alaska, Siberia and Europe have been generated, available on the Internet and on DVD free of charge for research and educational purposes.

The GBFM project also entails research activities in North America, Siberia and northern Europe, aimed at advancing scientific applications of L-band SAR data in the boreal zone.

1. BACKGROUND

1.1 GBFM Partners

The Global Boreal Forest Mapping (GBFM) project is led by the Earth Observation Research and applications Center (EORC) of the Japan Aerospace Exploration Agency (JAXA), but relies strongly on international collaboration. The NASA Jet Propulsion Laboratory (JPL), in cooperation with the Alaska Satellite Facility (ASF), is responsible for mosaic and applications development in North American zone, while the E.U. Joint Research Centre (JRC), in cooperation with VTT/Finland, are in charge of Siberia and Europe.

A regional research programme for Northern Europe, funded by the Swedish National Space Board (SNSB), was carried out 1997-2002 by the National Land Survey/METRIA.

1.2 The JERS-1 satellite

The Japanese Earth Resources Satellite (JERS-1) was launched by JAXA (then, NASDA) in February 1992, staying in operation for 6.5 years, until October 1998. It carried an L-band (1275 MHz/23.5 cm) SAR which operated with HH polarization and a fixed 35° off-nadir angle. Satellite repeat cycle was 44 days, with an image swath of 75 km.

Several features made JERS-1 particularly suitable for forest monitoring, most notably the low L-band frequency, which is more sensitive to vegetation structure than other (C-band) SAR instruments in orbit. L-band signals are also sensitive to standing water below the forest canopy - a unique characteristic among all contemporary earth observation satellites (both optical and microwave). A distinctive feature of JERS-1 was also that its orbit was designed so that adjacent passes were acquired on consecutive days. This results in an optimal 1-day time difference between neighbouring passes, and hence the capacity to acquire temporally homogeneous data even over large areas.

1.3 Pan-boreal SAR observations

Fine resolution remote sensing data are traditionally not acquired homogeneously over large areas, but instead typically collected with local focus over specific sites extending over one or a few scenes. Such approaches result in inconsistent and fragmented data archives that are inadequate for any application that requires extrapolation of locally developed methods and results to a regional or global scale context.

The importance of acquiring data in a spatially and temporally uniform manner over large regions was first demonstrated within the tropical GRFM project [1], where JERS SAR data were acquired with temporal and spatial consistency over the tropical belt of the Earth, enabling the development of unprecedented, regional-scale applications.

Building on this experience, the acquisition plans for Siberia, Europe and North America were designed for two seasonal covers - summer and winter - with acquisitions initiated during summer 1997 and continuing through the following winter, into summer 1998.

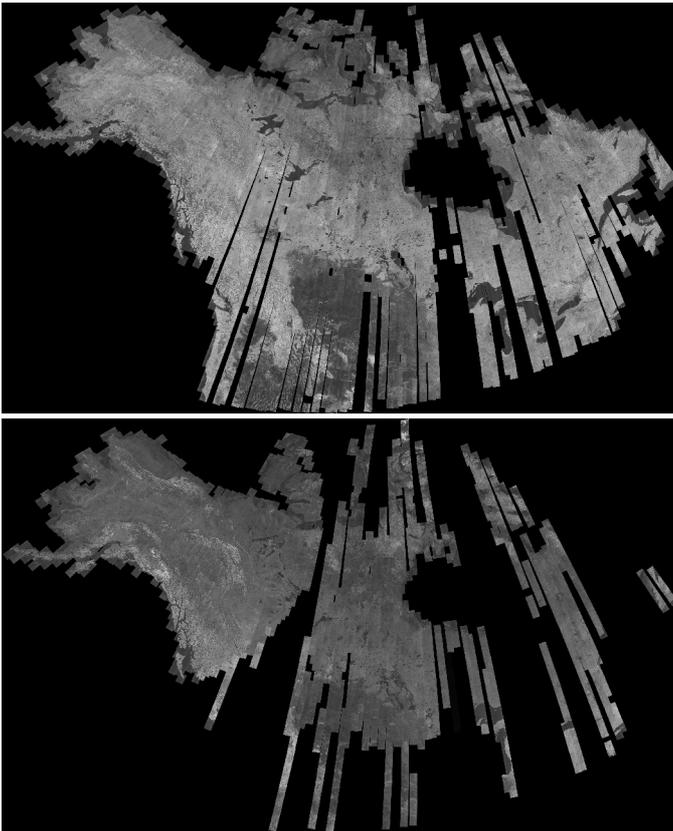


Figure 1. 100 m JERS-1 SAR mosaic coverage over North America. (a – upper) Summer, 1997. (b – lower) Winter, 1997/98
GBFM © JAXA/JPL/JRC

In order to reduce the total amount of JERS-1 SAR data to be acquired (by a factor 2), the GBFM observation plan focused on the circum-polar region north of latitude 54° , above which the extensive overlap between neighbouring swaths allowed the collection of every second – rather than each – satellite pass with maintained across-track coverage.

For acquisitions which extend below $N 54^\circ$, originally not planned to be utilised within the project, gaps between the passes become evident (Fig. 1a).

1.4 Tape recorder operations

Equipped with an on-board tape recorder, JERS-1 had the capacity for fast data access and full coverage also over regions without ground receiving stations. Having exceeded its designed life-time with several years however, raising bit error rates during recorder playback increasingly started to have a direct negative impact on data downlink, and the tape recorder subsequently had to be taken out of operations in September 1997, before the planned wall-to-wall winter acquisitions could commence. Without doubt, this caused a set-back for the project, which thus had to rely on non-complete archived data for the winter coverages (as illustrated for eastern Canada in Fig. 1b). In the case of Siberia, plans for dual-season mosaics had to be abandoned altogether as sufficient data for a satisfactory winter coverage could not be assembled.

2. GBFM MOSAIC GENERATION

2.1 Boreal North America

The North American component of the GBFM project covers the region of Alaska and most of continental Canada. The central and eastern Canadian coverage was dependent on the JERS-1 tape recorder operations and as a result, the most complete coverage was achieved during the summer of 1997, with fill-in data drawn primarily from 1994 and 1995 (Fig. 1a). The winter coverage is less comprehensive and was put together using archived data from, chiefly, the 1994/95, 1995/96 and 1996/97 seasons (Fig. 1b east). Much better coverage was achieved over the region covered by the Alaska Satellite Facility (ASF) ground station, over which near-complete seasonal coverages for the winter of 1997/98 and the summer of 1998 could be acquired. (Fig. 1b – west)

Raw data processing of all North American GBFM data was performed by ASF, who processed over 16,000 scenes to support the mosaic assembly. The Jet Propulsion Laboratory (JPL) in turn, was in charge of geometric and radiometric post calibration of the SAR data and ensuing, generation of the corresponding SAR image mosaics. Drawing on the multi-year database, 2,085 winter scenes and 3,076 summer scenes were assembled to create the mosaics. The mosaicking software used was a modified version of the code developed by JPL for South America within the GRFM project [2].

In order to maintain highest radiometric quality, full resolution scene products (ground range, 4 looks, 12.5 m pixels), filtered to 100 m spatial resolution by block averaging, were used as base for the mosaic development, in which also texture (coeff. of variation) mosaics were generated.

Finalized in late 2002, the multi-season backscatter and texture mosaics are given in Albers Equal Area projection with a pixel spacing of 100 metres. More background on the North American GBFM component can be found in [3-7].

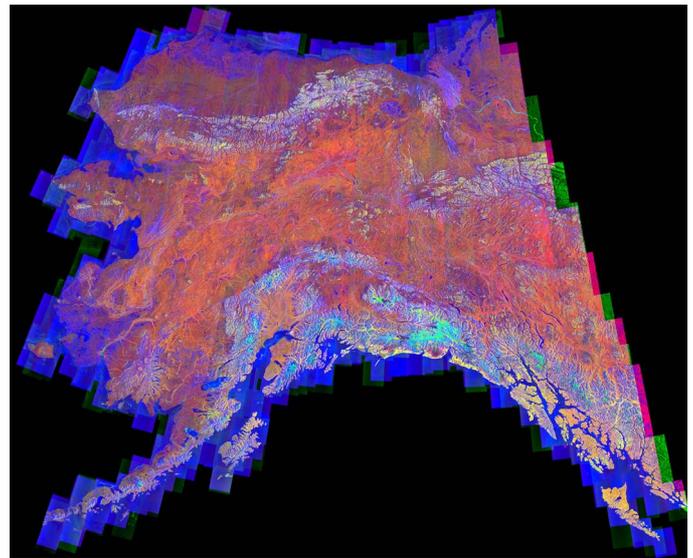


Figure 2. Multi-temporal GBFM mosaic over Alaska (R:1997 summer; G: 1997/98 winter; B: 1997 summer- texture). GBFM © JAXA/JPL/JRC

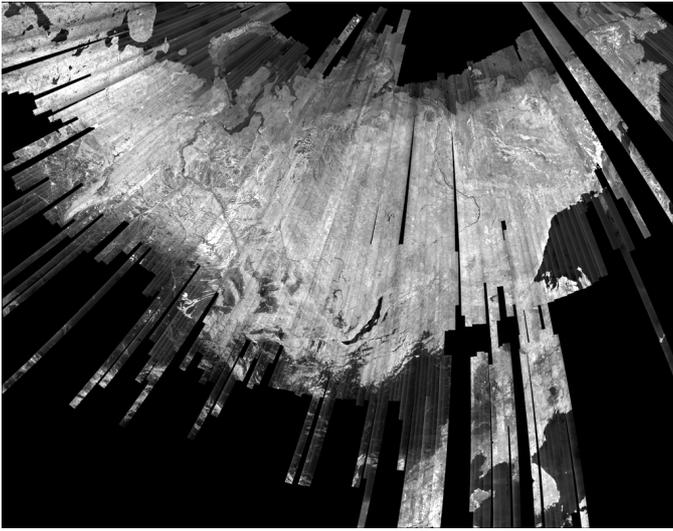


Figure 3. 100 m JERS-1 SAR mosaic over Siberia (1997). (incomplete draft). GBFM © JAXA/JRC/JPL

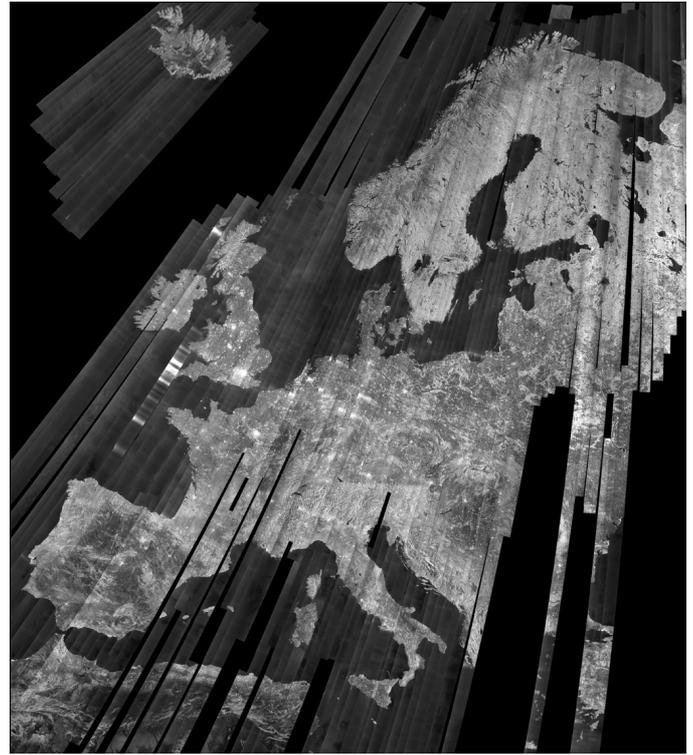


Figure 4. 100 m JERS-1 SAR mosaic over Europe (1997/98). (incomplete draft). GBFM © JAXA/JRC/JPL

2.2 Siberia and Europe

The JERS-1 coverage over the Eurasian continent arcs over some 210 longitude degrees along the coast of the Arctic Sea, from Bering Strait and Kamchatka in the east, to Iceland, Ireland and Portugal in the west.

The Siberian half, east of the Ural Mountains, covers most of the territory of Asian Russia, north Mongolia, and northeast China, encompassing an area of roughly 20 million km². About 80% of the JERS data used within the project were acquired between April and September 1997, during which the on-board tape recorder was drawing its last breaths. The remaining data were obtained from the JERS 1993-1996 archives, with preference for summer data when available, to minimize seasonal-induced backscatter differences in the resulting mosaics. Less than 3% of the data used were acquired during any of the months of October through March.

The European half extends from Norwegian Nordkapp well below the boreal zone to cover all of western and central Europe, as far as the islands of Malta and Cyprus in the Mediterranean. More than 80% of the data used were acquired between May 1997, and August, 1998 – a significant part of it by the ground stations operated by the European Space Agency, ESA. About 15% of the European coverage comprises of winter (October -March) data.

Raw signal processing of all SAR data, including the share acquired by ESA, were performed by JAXA, using the SIGMA-SAR processor developed at the EORC [8]. In contrast to the scene-based processing performed for the North American component, the Eurasian JERS data were processed to continuous swath images, some 80 km wide and up to 2500 km long.

The E.U. Joint Research Centre (JRC) in Ispra, Italy, in collaboration with Finnish VTT Information Technology, was responsible for the generation of the Eurasian mosaics. Based on algorithms developed by the JRC within the GRFM framework for calibration and generation of JERS-1 mosaics

over Africa [9], the software was modified to comply with continuous path data and extensive, non-linear overlap between passes. 100 metre pixel spacing path images - generated from full resolution (18 m) path data by B-spline filtering – were used as input in the global block adjustment programme, which is described in detail in [10, 11].

Some 535 passes were required for the full Eurasian mosaic, corresponding to approximately 8500 JAXA standard (75*75 km) scenes, or 6300 ASF-size (75*100 km) scenes.

Figure 3 and 4 show draft versions of the mosaics – still incomplete with significant data gaps - but illustrating their extreme geographical coverage. In agreement with their North American counterparts, also the Eurasian mosaics – backscatter and radar texture – are produced in Albers Equal Area projection, with a pixel spacing of 100 metres.

2.3 GBFM Data Sets

All mosaics generated within the GBFM framework are available free of charge for research and educational purposes. The North American data sets are presently available on DVD, and the corresponding Eurasian products are scheduled for completion and subsequent DVD distribution in late 2004.

To order a DVD, send an email request to JAXA (aproject@eorc.jaxa.jp), JPL (kyle.mcdonald@jpl.nasa.gov) or the JRC (frank.de-grandi@jrc.it).

Low resolution versions of the mosaics (500 m and 2 km) are available on the Internet for browsing and downloading at: JAXA: <http://www.eorc.jaxa.jp/JERS-1/>
JPL: <http://southport.jpl.nasa.gov/GBFM>

2.4 The North European Research Programme

While no official PI programme was undertaken by JAXA within the framework of GBFM, a small regional research programme for Northern Europe, funded by the Swedish National Space Board (SNSB) and managed by the National Land Survey/METRIA, was initiated in 1997 to stimulate and advance L-band SAR research and applications development relating to boreal forestry in Northern Europe [12]. The announcement attracted 13 investigators, out of which 9 completed their projects. As no mosaic data were available at the time, research projects were performed on a local-scale, using standard fine resolution scene products.

The research programme was concluded with a workshop held in Stockholm in February 2002. Proceedings from the meeting are published on CD-ROM [13], and are available on request from SNSB (maria.nilsson@snsb.se) or METRIA (hans.jonsson@lm.se).

3. CONCLUSIONS

3.1 Summary

Spanning around the entire boreal zone from Canada, via Siberia, to Iceland, the GBFM mosaics represent, without doubt, one of the most extensive sets of fine resolution mosaics ever created. As full resolution imagery were used as basic input data, the effective number of looks for each 100 m pixel exceeds 200, hence making the GBFM mosaic radiometry distinctly superior to that of mosaics with similar pixel spacing, but assembled from e.g. ScanSAR data.

The potential shortcomings of the GBFM data sets rather lie in the incomplete spatial coverage and temporal inhomogeneities, which nevertheless prevail over certain areas, thus highlighting the need for a concept change in mission planning.

3.2 Future prospects

Taking lesson from the JERS-1 experience, JAXA is implementing an entirely new acquisition strategy for the forthcoming Advanced Land Observing Satellite (ALOS) [14]. Focusing on achieving regional- to continental-scale consistency in both time and space, dedicated observation schemes are being implemented for all three sensors (PALSAR, PRISM, AVNIR-2) in which all land areas are to be acquired on a repetitive basis during the lifetime of ALOS. Abandoning traditional, local-focused instrument operations, which result in scattered and fragmented data archives, the aim is set on providing time series of regionally consistent data which allow multi-resolution, multi-scale analysis.

As a follow-on to the GRFB/GBFM activities, JAXA has initiated a new international collaborative project for ALOS - the Kyoto & Carbon Initiative - set out to exploit the ALOS systematic archives to provide better tools to address climate change, multinational conventions, environmental conservation and other cross-border issues of public interest [15]. Amongst others, global 50 m dual-polarization PALSAR mosaics are in the pipeline. Stay tuned...

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