

THE BRAZILIAN EXPERIENCE ON MAPPING FROM SATELLITE DATA

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COMMISSION IV

ABSTRACT

INPE, the Brazilian Institute for Space Research, has begun processing MSS data from LANDSAT-1 in 1973 and, since that, has made efforts to introduce the use of this kind of data to map the country. The results achieved with MSS data from LANDSAT-1,-2 and -3 were modest, due to a variety of reasons, but with them a great experience was developed in fields related to geometric and radiometric corrections, special treatments for cartographic applications, etc. With the advent of the TM data, in LANDSAT 4 and 5, INPE has developed a system for the geometric corrections of the images based only on the satellite telemetry data reaching very good results. Since that, the use of satellite imagery for mapping gained new perspectives, with the development of image treatments in digital form, mosaicking and progress in the printing process, which allowed the generation of image maps with much better quality. This paper presents an overview of the development of the techniques and efforts made in Brazil to introduce the use of satellite data in cartographic applications, from the early efforts based on MSS images, to the perspectives opened with the availability of real time TM and SPOT data and other sources from future satellites.

1. CARTOGRAPHY - A VITAL TOOL FOR THE DEVELOPMENT OF BRAZIL

Brazil is a developing country with an area slightly little over 8,500,000 square kilometers, not totally known with respect to its natural resources which are important elements of its economical base. The dynamic character of the processes that contribute to the social, economical and technological development of a country like Brazil determine the establishment of a Cartographic System to support the governmental action, its priorities and goals. Unfortunately, the area of cartography in Brazil received low priority and consequently insufficient funds up to 1977. Only 44% of the country had been adequately mapped in the scales 1:250,000 of 1:1,000,000 when a National Cartographic Plan was approved in 1978. Despite the difficulties to carry out this plan the present situation can be considered reasonable since 83% of the total area of the territory is already mapped in appropriate scales for planning activities (1:250,000, 1:100,000 or 1:50,000). However, there is a lot to be done in the domain of the thematic and special cartography in addition to the activities related to the topographic mapping in large scales (1:25,000, 1:10,000, etc.) in selected regions. It is recognized by the international community that remote sensing data becomes an effective tool to support mapping activities in developing countries. In Brazil, thanks to its experience of about 15 years in handling remote sensing data for the evaluation of natural

resources and monitoring of environment, the use of this new technology in cartography, under operational basis, can be considered as an important and viable process.

The development of "Projeto RADAMBRASIL" which mapped the entire country using a SLAR (Side Looking Airborne Radar) for the production of thematic maps in 1:1,000,000 scale and planimetric maps in 1:250,000 scale, created the basic conditions for the use of non-conventional data in cartography. Afterwards, and following for the recommendations of the Second Regional Cartographic Conference for the Americas, sponsored by the UN and held in Mexico City, September 1979, the Brazilian Institute for Research Space (INPE) has conducted efforts in the area of geometric corrections modelling in order to allow the more effective use of LANDSAT-MSS data, received and processed by its ground station, in the cartographic domain. Some important results were obtained which proved the convenience of the process.

Today, INPE, in cooperation with other governmental agencies, is carrying out additional tests, now using satellite data of new generation (LANDSAT-TM and SPOT-HRV). Although taking into account some present limitations these satellite data have been already used as a reliable information for the simple revision of maps already published, as a basic material in regions not yet mapped and for the production of thematic and special maps.

2. BACKGROUND ABOUT THE USE OF REMOTE SENSING SATELLITE DATA IN THE AREA OF CARTOGRAPHY

Signals from the LANDSAT satellites are received since 1973 in the country by the Ground Tracking and Receiving Station, in Cuiabá, strategically located to allow a coverage not only of all the Brazilian territory, but also of several neighbouring countries. The data is recorded on magnetic tapes which are sent, by air, to São Paulo, and afterwards, by land to Cachoeira Paulista, where the processing center is located.

From March, 1988 on SPOT-1 data are being routinely acquired and processed in Brazil using the same LANDSAT facilities that were recently upgraded.

2.1 - THE EXPERIENCE USING LANDSAT-MSS DATA

MSS data are being continuously produced since 1974 by INPE's Processing Center in a mode called "bulk". Summarily, the geometric precision of the MSS bulk images is a result of the following factors:

- a) quality of the existent ephemeris data;
- b) quality of the telemetry data;
- c) projection model used;
- d) systematic errors of the hardware and/or software;
- e) photographic distortions;
- f) parameters associated to the sensor device (non-linearity, off-sets, etc.) although considered in the software.

Considering that perfect positioning of the latitude and longitude marks in the image (tick-marks) is function of the ephemeris data which cannot be easily refined without the use of ground control points (GPC's) INPE has adopted as a philosophy the fact that these marks in the bulk process must be only used as reference, since errors up to 2.0 km can be found. The most important thing, undoubtedly, is the internal accuracy. Several tests showed that this internal error in the bulk process adopted by INPE varies from 1 to 2 MSS pixels (80 meters). A precision process of MSS data, which would minimize internal errors by the addition of well distributed control points in the image, was discarded due to the lack of good maps at least in 1:50,000 scale (today, only 13% of the Brazilian territory is mapped in this scale!) and the cost associated with the use of doppler stations in regions of difficult access.

The interest in contribution to the solution of some problems in the area of cartography of small scales, oriented INPE to the establishment in 1980 of two pilot projects: one, with the Electronics and Flight Protection directory (DEPV) of the Ministry of Aeronautics, and another one, with the Geographic Service Directory (DSG) of the Ministry of the Army.

In the case of DEPV, the area chosen was the Volta Redonda chart (Aeronautical Piloting Chart) and the imagery was used not only as a planimetric base, but also for the extraction of some topics. INPE was responsible for providing two mosaics (MSS bands 5 and 7) at the scale 1:1,000,000 to DEPV, both mosaics having the necessary imagery to cover Volta Redonda chart. These mosaics were afterwards enlarged and rectified by conventional methods for the 1:250,000 scale. From there on, operations were carried out for the extraction of topics, color separation, symbolization, etc., all of these operations being under the responsibility of DEPV.

The final product, the experimental sheet CAP-9489 of Volta Redonda was presented at the 14th International Congress of the International Society of Photogrammetry, in Hamburg, July 1980, in the paper entitled "LANDSAT Images as Planimetric Bases for Aeronautical Charts".

Said first encouraging result permitted INPE and DEPV to start discussing a much broader agreement, that was signed by both parties.

In the case of DSG, the area chosen was the Brasilia chart, the mosaic of the LANDSAT images being used as a planimetric base and the topics information extracted from available maps at the scale of 1:1,000,000. The responsibility for the additional work involved was entrusted to the DSG. Several tests were carried out in order to obtain a perfect match of the information (video) from the LANDSAT images with the existing ones in the maps being used. The results were not as good as expected, but were sufficient enough to show that updatings could be done in the existing maps, from the LANDSAT images, principally those relating to urban areas, rivers and lakes, highway network and others that are necessary due to the dynamics involved.

Despite this, and considering that better results could have been obtained with a greater control over the rectification and printing processes, INPE and the DSG decided to sign an agreement on September, 1980, for the production of image maps of the Brazilian territory.

Many countries have been also image mapped at small scales with LANDSAT-MSS data. These maps are generally of 1:500,000 or smaller scales. The MSS data is capable of being reproduced in acceptable form at scales as large as 1:250,000. For example, today, the U.S. Geological Survey distributes over 30 LANDSAT-based image maps of portions of the United States and 9 or foreign areas, and these maps meet or at least approach the U.S. standards for positional map accuracy, except for these of foreign areas where little or no ground control was available (Colvocoresses, A. - The Status and Future of Satellite Image Mapping, 1984).

Similar experiences carried out in various developing countries of Africa, Asia and South America, with the financial support of international agencies such as the World Bank, Interamerican Developing Bank, etc. are also known.

2.2 - OPERATIONAL ACTIVITIES USING LANDSAT-MSS DATA IN MAPPING

The Brazilian Satellite Remote Sensing Program created in 1973, whose leading organization is INPE, has as main objectives the reception, processing and dissemination of remote sensing data, and the developing of methodologies in the evaluation of natural resources and monitoring of the environment. After the period called "demonstration phase" the program today focuses on the transference to the user community of the know-how, technology and related methodologies developed. Up to now a great number of application methodologies have been developed in the country and satellite remote sensing can be considered as a reality in Brazil. Naturally, the availability of MSS data played an important role in this process. Dozens of Brazilian agencies from both government and private sectors are using today satellite data in its operational activities and thematic maps are being produced in different areas of application, scales and shapes.

As far as mapping is concerned and the contribution to the National Cartographic Plan the use of MSS data under operational basis is assured. DSG is periodically requesting data to update the topographic maps under its responsibility (1:250,000 and 1:100,000 scales), besides the production of special maps of military application mainly for training purposes. Nowadays TM data is replacing MSS data in these applications.

IBGE (the Brazilian Institute for Geography and Statistics), the most important cartographic agency in Brazil, also uses satellite data to update the topographic sheets under its responsibility and today analyzes the possibility of printing several image-maps in the Amazon region.

DHN (the cartographic agency of the Ministry of Navy) and DEPV have already demonstrated the interest in this technology with the development of pilot projects, but the operational

application will be only possible in a near future with the use of high resolution LANDSAT-TM or SPOT-HRV data.

Obviously, the availability of LANDSAT-TM data since 1983, opened a new horizon to the area.

The efforts being conducted by INPE and other Brazilian cartographic agencies are presented below.

2.2 - THE ACHIEVEMENTS WITH THE USE OF LANDSAT-TM DATA

The launch of LANDSAT-4 satellite carrying the Thematic Mapper sensor, in July, 1982, made available data more suitable for cartographic applications, due to the 30 meters resolution, and the much better stability of the platform, which leads to image acquisition with less geometrical distortions.

INPE has finished the installation of its Thematic Mapper Image Processing System in march, 1983. This system, a significant improvement when compared to the old MSS processing system, is able to treat the images at much more precise levels of geometric corrections. The geometric corrections system makes use of a complete model of the acquisition system to compute the mapping of the input image elements into its position in the output products, based on the payload correction data, without the introduction ground control points to achieve a good internal accuracy.

Photographic products are generated from the input pixels (with no resampling) by the use of an electron beam recorder. The position of each pixel in the output film is controlled by the deflection of the electron beam which exposes the film. For each point in the image, the recorder receives the value of the grey level (which controls the beam intensity) and its coordinates (which control the deflection of the beam).

Images generated by the method described above were evaluated by comparison with existing maps, showing an internal geometric distortion better than the resolution of the Thematic Mapper, that is, less than 30 meters (RMS).

This process of image generation with no need of resampling to perform the geometric corrections is very efficient and allows the production of a full TM image frame in 28 seconds, but applicable only to film products. The unavailability of the corrected image in digital form imposes some limitations to the digital treatments that could be used to the generation of cartography-oriented products. This has led to the development of a procedure of mosaicking the images on film, for the generation of cartographic documents in 1:250,000 scale.

The mosaicking procedure is based on the very good geometric consistency of the TM images. The overlap area between the images is registered manually, and the mosaic is generated by the scanning of part of each one of the images while exposing the output film. This process makes use of a Topocart/Ortophoto system manufactured by Zeiss-Jena.

The above procedure was used to generate the three mosaics on film for the first TM image-map, in the scale of 1:250,000 over the region of Barbacena, in Minas Gerais state. This product showed good geometric quality, and has caused a good impression at the time of its presentation, although not making use of all potentiality of TM data. Much more information could be available if the data had been treated in digital form, by suitable processes.

In 1986 a system was developed at INPE to resample the TM data to generate a corrected image in digital form, at the same level of accuracy of the image on film. From the corrected images, there was no difficulty to implement the digital mosaicking, making possible the use of digital treatment techniques to generate image-maps with better visual quality.

The possibility of the generation of image-maps from TM data was recognized by the establishment of an interinstitutional working group, on October, 1986, where INPE is responsible for the image processing up to the generation of the mosaics on film. Other phases of the production of the map, like interpretation, plotting and printing are made by other organizations, in a coordinated work.

Under the orientation of the working group, band selection and colors choices were discussed, aiming to the printing of a better quality product. As a result, the first image map made from a digital mosaic of TM data was printed, over the same region of Barbacena. This product was presented at the Brazilian Congress of Cartography in Brasília, in July, 1987, with a great success.

The evaluation of the geometric quality of the Barbacena image-map from the TM digital mosaic showed a value of 60 meters (RMS) for the internal accuracy, and the final product presented a visual quality greatly improved with respect to the former experiments. The quality of this product was recognized by the interested sectors, and positively impacted the decisions of COCAR, the Commission of Cartography of the Ministry of Science and Technology, responsible for the National Cartographic Plan. Today, COCAR recognizes the importance of using orbital data to the production of planimetric image-maps thematic and special maps and the update of conventional topographic maps already published.

3. PRESENT SITUATION AND FUTURE WORKS

The establishment of the image-map working group, its support by COCAR in March, 1987 and the recognition by the community of the quality of the image-map generated by digital mosaic of TM data open the perspective of the use of this product as an important tool in the mapping activities of the Brazilian territory.

Presently INPE is developing methods to the use of satellite data in mapping at 1:100,000 and larger scales. This is possible by the application of spatial filtering and enhancing techniques to TM of SPOT-HRV data. Methods to geometrically correct SPOT-HRV imagery to levels more suitable for cartographic

applications are under development, as well as methods to combine panchromatic data, (10 m resolution), with multispectral data (20 m or 30 m resolutions).

Also, in order to make more efficient the use of satellite data combined with other sources in cartographic applications, INPE is finishing the development of a geographic information system (GIS), based on microcomputers manufactured in the country.

The development of methodologies for the effective use of these data will continue to be emphasized taking into account the future availability of data from new generation satellites like ERS-1 of the European Community, RADARSAT of Canada and the LANDSAT and SPOT series.

Not only that, but INPE is also responsible for the development of application satellites within the Brazilian Space Program. This includes the construction of two remote sensing satellites to be launched in early 90's. It is expected that the availability of remote sensing data from Brazilian satellites will give important contributions to the development of the country and its cartography.

Technological development in the space activities which will be achieved in this next decade will certainly make easier the task of the cartographers in mapping the world.

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