Spanish National Remote Sensing Program, a way to achieve massive use of remote sensing data

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Abstract. Spanish National Remote Sensing Program (PNT) provides regular coverage of the Spanish territory with current and historical satellite imagery. This imagery is acquired with multi-user licenses for all Spanish Public Institutions, and processed once with geometric and radiometric processing agreed by experts of Spanish scientific community, and it is distributed to all users from Spanish Public Institutions. This way, we promote the massive use of remote sensing data. Spanish imagery is structured in three levels of spatial and temporal resolution: (i) High resolution: Images from 2 to 10 m of spatial resolution in panchromatic mode and from 10 to 30 m in multispectral mode. It is acquired a complete coverage every year with summer images. From 2005 to nowadays SPOT5 satellite is selected to provide that type of resolution. In future, with Spanish high resolution satellite called Ingenio, we will have several annual coverages. (ii) Medium resolution: Images from 10 to 15 m of spatial resolution in panchromatic mode and from 20 to 50 m in multispectral mode. It was planned to acquire at least four coverage every year, but since January 2008 all Landsat5 (TM) imagery captured over Spain is acquired. During 201, as well, Spot4 and Deimos1 images are being acquired. (iii) Low resolution: Multispectral images from 50 to 1000 m of spatial resolution, with a periodicity of 1 or 2 days. MODIS and MERIS sensors are the main source of this type of resolution. Nowadays, in PNT, more than 2000 images are processed every year to obtain derivate products such us georeferenced images, mosaics of images, etc. To reduce the time between the collection of data and the moment the information is available, PNT has designed a storage infrastructure suitable to the volume of information, an appropriate workflow, distribution control and an efficient spreading.

Keywords. Spanish National Remote Sensing Program – PNT – Satellite imagery – Image proccesing.

Le Plan National de Télédétection, un moyen de parvenir à une utilisation généralisée de l'information de télédétection

Résumé. *Le Plan National de Télédétection (PNT) offre une couverture régulière du territoire espagnol avec des images satellites actuelles et historiques. Cette imagerie est acquis avec licences multi-utilisateurs pour toutes les institutions publiques espagnoles, et traitée avec un traitement à la fois géométrique et radiométrique accepté par les experts de la communauté scientifique espagnole, et finallement elle est distribuée à tous les utilisateurs des institutions publiques espagnoles. De cette façon, nous favorisons l'utilisation massive de données de télédétection. L'imagerie espagnole est structuré en trois niveaux de résolution spatiale et temporelle: (i) Haute résolution: Images de 2 à 10 m de résolution spatiale en mode panchromatique et de 10 à 30 m en mode multispectral. Il est acquis une couverture complète chaque année avec des images d'été. De 2005 à nos jours, le satellite SPOT5 est sélectionné pour fournir ce type de résolution. À l'avenir, avec le satellite de haute résolution espagnole appelé Ingenio, nous aurons plusieurs couvertures annuelles. (ii) Moyenne résolution: Images de 10 à 15 m de résolution spatiale en mode panchromatique et de 20 à 50 m en mode multispectral. Il était prévu d'acquérir au moins quatre couvertures chaque année, mais depuis Janvier 2008, tous les images Landsat5 (TM) capturées sur l'Espagne ont été acquises. En 2011, les images Spot4 et Deimos1 sont aussi en cours d'acquisition. (iii) Basse résolution: les images multispectrales de 50 à 1000 m de résolution spatiale, avec une périodicité de 1 ou 2 jours. Les capteurs MODIS et MERIS sont la principale source de ce type de résolution. Aujourd'hui, dans le PNT, plus de 2000 images sont traitées chaque année pour obtenir des produits dérivés tels que des images georreferencées, des mosaïques d'images, etc. Afin de réduire le temps entre la collecte de données et le moment où l'information est disponible, le PNT a conçu une infrastructure de stockage adaptée au volume de l'information, un workflow échéant, un contrôle de la distribution et une efficacité de propagation.*

Mots-clés. *Plan National de Télédétection – PNT – Imagerie satellitale – Traitement des images.*

I – Introduction

In this century, XXI, Spain has posed two challenges, both of them very important for its sustainable development, besides the intention of modernization, the impulse of the infrastructure and the concern about the environment. The recently dynamism of the Spanish society as well as the development of the whole country causes a great impact over our territory.

All of these aspects demand the availability of accurate information about the territory constantly updated and adapted to the geographical data standards (ISO, INSPIRE, IDEE...). The satellite images give the possibility to answer about the dynamic changes that are taking place in our territory. These images are also an important part of the geographical and environmental information. Therefore, the applications and the uses are increasing.

The Remote Sensing is a mature technique with even more applications than it used to have, some of them have reached such a development that makes them being in "operational phase". However, most of the techniques and their required processing are complex, so a great specialization and hard work is needed to apply them in the correct and efficient way. This drives us to the necessity to implement systematic production lines, properly designed and constantly improved.

II – Description of Spanish National Remote Sensing Program

1. Legal and administrative framework

The "Consejo Superior Geográfico" (CSG) is the advisory and planning agency of the Spanish State dealing with the geographical information. It depends on the Ministry of Public Works, being regulated by the Royal Decree 1792/1999, November, 26th. Its aim is the coordination of geographic information of Spain. Specifically, the CEOT (special commission of land monitoring) coordinates the photogrammetric flights and territory mapping from satellite.

Under the CEOT, it is created the group of general coordination of the project, formed by the Ministry of Public Works (through the IGN, CNIG), the Ministry of Environment and Rural and Marine Affairs, and the Defence Ministry (through INTA). Likewise, it has been named a Coordinator in every Ministry involved and in every Autonomic Community, to deal with the agreement and negotiate economic transfers needed to the development of the project.

2. Organization

Inside the PNT, different work groups by experts and users have been created in order to consolidate the requirements and identify solutions. The groups created until now are:

(i) Technology Groups: High resolution, medium resolution, low resolution, radar, biophysical parameters and spectro-radiometry and architecture computing, data and metadata.

(ii) Application Groups: Agriculture, forest and fires, agrienvironment index and other applications.

The technology groups have as the mission to define technical specifications of the products to be generated from the original images and productive processes to be implemented in the PNT.

The mission of the application groups is to write technical recommendations about complete processes to facilitate the hiring by the Public Administration of products and services of an added value from the images and basic data generated.

3. Imagery acquisition

The coverage considered on the Spanish National Remote Sensing Program are structured in three levels of spatial and temporal resolution: high, medium and low.

A. High resolution

PNT considers that high resolution is an image from 0.5 m pixel size to 10 m in panchromatic and from 2 m to 30 m in a multispectral. The acquisition forecast of this type of images is a complete coverage a year at least, preferably between June, 15th and September, 15th.

The main applications of these images are: to obtain land cover cartography (project SIOSE and project CORINE land cover of the European Union), updating cartographic database of medium and small scales, to obtain environmental and agricultural information, etc. It also may be obtained "Image Cartography" (Orthoimagery and Carthoimagery).

From 2005 to 2009, the high resolution sensor chosen has been the HRG on board of the satellite SPOT5. Images that this sensor captures are from 2.5 m pixel size in the panchromatic (1 band) and 10 m in the multispectral (4 bands). Other alternatives are Formosat or the Spanish satellite INGENIO (in a near future).

B. Medium resolution

PNT considers that medium resolution is an image from 10 m to 15 m pixel size in the panchromatic and from 20 m to 50 m in multispectral. The regular recurrence initially planned were at least of 4 coverage a year, but all the images taken from Spain by the satellite Landsat5 sensor have been acquired since May 2008.

The repetitive captured of information of the same zone is carried out with the aim to allow the multitemporal monitoring (intra and inter-annual) of environment and territory evolution. It is also useful for environmental management, design of plans and policies of prevention and emergency according to natural catastrophes, risky places, control of environmental quality, etc., in which remote sensing is combined with tools like Geographical Information Systems. Other applications are land cover automatic classification, crop identification, irrigated land detection, forest information, biophysical parameters, etc.

During current year, as well, Spot4 and Deimos1 images are being acquired over all Spanish territory. In the future Sentinel2 will also be available.

C. Low resolution

PNT considers as low resolution coverage with multispectral images from 100 m to 1000 m, of spatial resolution and periodicity from 1 to 30 days.

Low resolution data are used mainly to analyze the evolution of phenomena which change quickly along time, through the creation of biophysical parameters. The daily availability of the images of these sensors and of derivate parameters of them, facilitate the monitoring in nearly real Earth time, directed to the analysis of environmental variables.

So, main applications of the low resolution images are the extraction of the biophysical and environmental parameters (indexes of vegetation, temperatures, quantity of combustible materials, and risk of fire...) these parameters can facilitate the obtaining of standard environmental index by different world organizations.

The suggested sensors are AQUA/TERRA Modis and ENVISAT Meris (with 250 m and 300 m of maximum resolution respectively) Other complementary alternatives of very low resolution are: NOAA, AVHRR, SPOT Vegetation. In the future it will also be available Sentinel 3.

4. Image processing and derivate products

Each type of territory coverage: high, medium and low resolution, counts with its own set of data, work flow and products.

A. High resolution

Spot5 images are received with a processing level 1A. All the subsequent geometric processing, such as the radiometric treatments, is carried out at the National Geographic Institute.

a] Ground control points measurement and block adjustment

The unit LPS from software ERDAS is required. Blocks are formed with the pancrhomatic images and with the multispectral images: one for the whole peninsula and one for each island.

– Block preparation: definition of the geodetic reference system, type of images to be corrected, mathematical model which is going to be used and charge images in the block.

– Ground control points measuring: Around 13 control points are taken per image measuring their terrain coordinates from aerial orthophotographies with 0.5m of pixel size.

– Block adjustment and mathematical model parameters calculation: One only adjustment is required on the block getting a unique set of parameters of the model for each image.

– Block images orthorectification. Finally, the calculated parameters are applied to every image to be transformed into the desired geodetic reference system.

b] Geometric correction

Including ground control points coordinates and tie points coordinates in one only block adjustment, images are georeferenced. The geodetic reference system used is ETRS89, projection UTM.

An exhaustive visual quality control is carried out to make sure there are no geometric deformations in the generation process of corrected images. Besides, a geometric control of the mentioned images is made through the measurement of 10 check points in each image. Check points are measured over panchromatic image and distributed regularly over a mesh defined by technical direction; they are different from ground control points. The check point medium error obtained should be smaller than 1,5 pixels and maximum error in any point, smaller than 2 pixels.

The panchromatic and multispectral images are resampling by bicubic interpolation method, and also by nearest neighbour with multispectral images.

c] Pansharpen

Trough pansharpening it is obtained an image with the same spatial resolution as panchromatic image and same spectral resolution as multiespectral image.

To make pansharpening is used "Fast SRF" method created by María González de Audicana, from Navarra University. This method has the best relation quality-processing time.

d] Radiometric balance

Radiometric balance is used to homogenize the radiometry of images to obtain a continuous mosaic. All radiometric values of all Spot5 images are transformed into radiometric values of a reference image trough a lineal mathematical transformation: $y = a*x + b$. This equation is applied band to band. Formulas to obtain "a" and "b" parameters are:

$$a = s1 / s2$$
$$b = \mu 1 - \mu 2\ (s1/s2)$$

s1: Standard deviation of reference image.

s2: Standard deviation of image to balance.

μ1: Average of reference image.

μ2: Average of image to balance.

A MODIS image has been used as reference image to make balance in 2005. Later date, mosaic generated in 2005 with all spot5 images has been used as referenced image to make new balance.

e] Band combination

Four band combinations are generated: classic false color, assigning bands 321 to RGB colour mode, Corine false colour, assigning bands 342 to RGB colour mode, natural pseudocolor, assigning bands 432 to RGB colour mode and SIOSE natural pseudocolor which is a mixture of 50% from SIOSE natural pseudocolor and a natural color that is derived from a synthetic blue.

f] Enhancement

It is used to obtain an easy image to interpret and consist of a contrast lineal expansion for red, green and blue bands. After that, a gamma function is applied for getting brightness. Enhancement is determinated for each separate portion of land. Only one enhancement is calculated for the penninsula mosaic and it is applied to all mosaic images. As well, different enhancements are calculated for each Spanish island and they are applied to all images of each island. These enhancements were determinated in 2005. From 2006, balance and enhancement are applied to images at the same time because the reference image which is used is mosaic generated in 2005 (which is already enhanced).

g] Mosaics

One mosaic is obtained for Spanish peninsula and Balearic Island and another one for Canary Island. Mosaics are made in different band combinations: natural pseudo-colour and false colour (Fig. 1). Break lines are calculated for repairing big radiometric differences that balance could not save. In 2005 and 2008, Spanish territory was completely covered with high spatial resolution images, so there are two hold mosaics for these years. There is another Spanish coverage within 2006 and 2007, so one mosaic was made for these two years. From 2009 to future an "incremental mosaic" is generated adding new images to most current mosaic for the moment, so users could see the most recent data for each surface point.

B. Medium resolution

Landsat images are received with a level processing called 1G (only sensor deformations). All geometric and radiometric processing subsequent is carried out within Spanish National Remote Sensing Program. The main steps of processing are:

a] Geometric processing

– Ground control points measurement and block adjustment: it is a process similar to that made with to high-resolution images but measuring 33 control points per image.

– Geometric correction: project image to ETRS89 geodetic reference system.

Fig. 1. Pseudo natural color Mosaic with Spot5 images.

b] Radiometric processing for optical wavelength

– Radiance calculation: Radiances are calculated from sensor calibrations coefficients trough next mathematical equation:

$$L_\lambda = G \cdot ND + B$$

L_λ: radiance obtained by sensor (W·m-2·sr-1·μm-1), ND: image digital levels,

G: gain,

B: bias.

– TOA Reflectivity calculation: next mathematical formula it is used:

$$\rho TOA = \frac{\pi \cdot L_\lambda \cdot d^2}{E_{0,\lambda} cos\theta_s}$$

d: land-sun distance at the moment of image capture, expressed in astronomical units (ua).

L_λ: spectral radiance, calculated as in the previous case.

$E_{0,\lambda}$: spectral solar exoatmospheric irradiance.

θ_s: solar zenith angle.

– Atmospheric correction. It is used "dark object model", developing by Chavez (1988; 1996).

$$\rho = \frac{\pi * \left[L - L_a \right] * d^2}{cos\theta * E_0 * \tau_1 * \tau_2}$$

ρ: reflectivity, E_0: spectral solar exoatmospheric irradiance (W·m^{-2}·μm^{-1}), τ_1: atmospherically transmission coefficient on the road Sun-Land, τ_2 : atmospherically transmission coefficient on

the road Land-Sensor, L_a: radiance witch is received by the sensor in an area where there is only atmospheric contribution (area of shadow or water according to the spectral region), L: radiance of the pixel to correct, θ: solar zenith angle and d: land-sun distance, in astronomical units.

– Topographical correction. The empirical-statistical method is used. This is the mathematical algorithm:

$$\rho_{\lambda,h,i} = \rho_{\lambda,i}\, cos\, \gamma_i\, m_\lambda - b_\lambda + \bar{\rho}_{\lambda,i}$$

ρλ,h,i: pixel reflectivity in horizontal land.

ρλ,i: pixel reflectivity in steep land.

$\bar{\rho}_{\lambda,i}$: Reflectivity average of all ρλ,i.

γ_i: incidence angle in a pixel i.

bλ: origin ordinate of the linear regression among γ_i and $\rho_{\lambda,i}$.

m_λ: slope of the linear regresion among γ_i and $\rho_{\lambda,i}$.

C. Low resolution

Images will be acquired in real time using Spanish receiving antennas. Raw data (.pds format) will be transforming into level 1b which are radiance and reflectance at sensor, TOA radiance, TOA reflectivity and observation and illumination angle and georreferenced data. So next values will be calculated:

– TOA radiances and TOA reflectance, RAD-TOA and REF- TOA.

– Latitude and longitude, observation and illumination angles.

– TOA radiances and TOA reflectance for georeferenced images.

TOA radiance will be transform into radiometric temperature (Trad-TOA) for infrared channels according to Planck law. Finally, georeferenced images will be projected to geographic coordinates.

Derivate products will be:

– Radiative products: radiance at sensor, temperature at earth's surface and normalized reflectance at earth's surface.

– Biophysical products: Normalized Difference Vegetation Index (NDVI), Fraction of Vegetation Cover (FVC), Leaf Area Index (LAI) and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR).

5. Dissemination of images and derivate products

There is a working Group in PNT called "Architecture and data" aimed at defining and establishing all items in storage and distribution in PNT project. Storage and distribution must satisfy the following requirements:

(i) *Organized and accessible storage for all generated information*. Needs of hard drive for all generated information in PNT Project reach the amount of 9 Terabytes each year for more than 17.000 images. This disk volume will be increase with the images of "Historic PNT Project" (to acquire all the images captured by different sensors of Landsat constellation from their launch), whose estimated needs of hard drive are about 40 Terabytes. Moreover, it must be remembered the possibility to incorporate coverage from other satellites to PNT project.

To meet the first requirement, it has an EVA array formed by a disk array with enough capacity for storing all current information and possible to expand the storage volume in future. By

implementing a document manager for the Project provides a tool for managing information: definition of metadata-based searches and data organization, allowing the possibility of incorporating a process Management system.

(ii) *Efficient distribution according to the priorities of access*. We must have a bandwidth appropriate to the size of the files and the Lumber of users connected so that the response time is acceptable. Currently, data and derived products are distributed via FTP.

(iii) *Control of the information distribution as data policy says*.The medium and high spatial resolution images are acquired with a multi-user license restricted for Spanish Public Administration, Universities, Public Investigation Agencies and Companies working for Public Administration.

(iv) *Normalization.* To meet the last requirement of the PNT Project in storage and information distribution are considered, among other regulatory issues, the implementation rules of the INPIRE Directive, International Standard ISO and OGC specifications. Derived products in PNT project have their ISO metadata in order to comply with INSPIRE Directive.

III – Current problems, solutions and future work

1. Description of the problem

The big drawback that satellite images users can find when working with them is the subject of the clouds. According to the International Satellite Cloud Climatology Project (ISCCP) estimates that our planet is permanently covered by clouds more than 60%.

From an operational standpoint, clouds are the most significant source of error to calculate the land surface reflectivity and have an adverse effect on most remote sensing applications, making useless many of the images acquired by different satellites.Therefore, the ideal thing to do it would be to eliminate the clouds of any image while preserving the land information.

Until now, the research has been focused on automatic clouds detection. Some detection algorithms have been developed for different sensors but what they get is a mask of clouds, leaving useless that part of the image.

2. Solutions and future works

The National Geographical Institute (PNT coordinator agency), Regional Development Institute of Albacete (IDR), Image Procesing Laboratoty U. Valencia (IPL), and Center for Ecological Research and Forestry Applications in Barcelona (CREAF), are working on a research project to obtain cloudless images from temporal series of images from different sensors with different spatial and temporal resolutions which are available for the same point on earth.

The idea is: using images from multiple sensors to determine the spectro-temporal reflectance surface (STRS) for each point of Earth surface and to make a surface model (Fig. 2). After creating the model of this surface, the reflectivity of any point of surface can be obtained, for any date and wavelength, where there is no baseline data (image).

Therefore, the cloud o fan image may be removed by replacing the radiometric values of affected pixels with the reflectance values corresponding to each pixel. To achieve this purpose it is necessary to deal with two concepts:

– Downscaling or upscaling. This is to transform an image pixel size to another to compare images with different spatial resolution. It allows homogenizing radiometric information from images with different pixel size.

– Temporal interpolation is to obtain information from the earth's surface of a date which there is no image captured, interpolating between the images captured before and after dates.

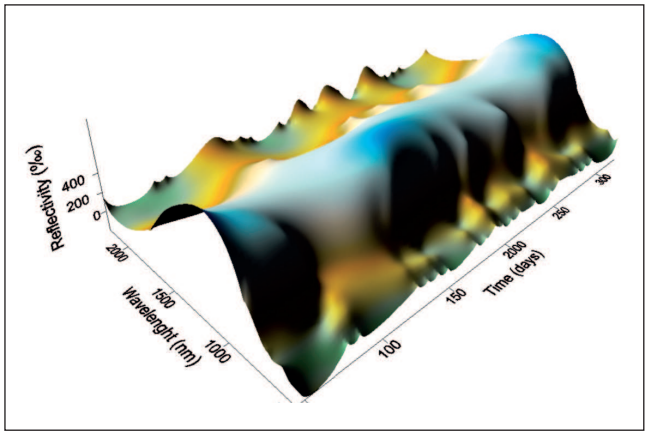

Fig. 2. Spectro-temporal reflectance surface example.

It is also necessary to introduce a new concept: the spectro-temporal reflectance surface (STRS) for each point of an image. From the beginning, in remote sensing each point of image (or Earth surface point) was characterized by its spectral signature (Fig. 3), i.e. by the reflectance value for each wavelength.

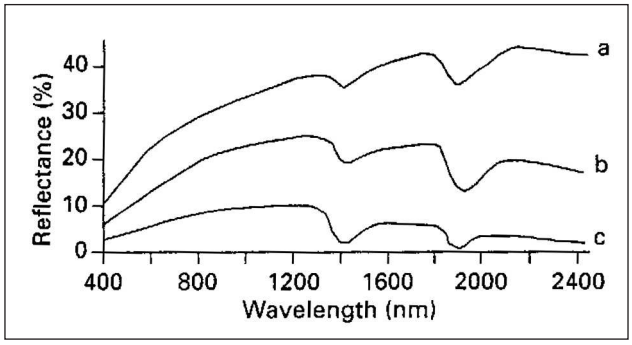

Fig. 3. Spectral signature example.

If time is added, this figure becomes a surface where reflectivity values are represented according to the corresponding wavelength and date.

Once known the STRS for each point on Earth, it would be possible to calculate reflectance values for this pixel of every date, including date where there is no images taken.

This way it is possible to replace radiometric values of pixels with clouds o fan image with reflectance values which represent the existing land bellow the cloud. As well, it is possible to generate synthetic images free of clouds of a desired date where there is any image capture by a satellite.

Future work will include improved methods of merging images of different resolutions (downsacaling and upscaling) and methods of interpolation to achieve better spectro-temporal reflectance surfaces, i.e, surfaces which represent much better the real values.

IV – Conclusions

Thanks to Spanish Remote Sensing National Program (PNT), it has been promoted the massive use of satellite images on multiple projects and jobs. PNT Project is responsible for coordinating the acquisition of satellite imagery, performing basic geometric and radiometric treatments on the images and distributing them to all the Spanish Public Administration, Universities and Public Investigation Agencies.

Now, one more step is intended by solving the major problem that all users of satellite images have for most applications in remote sensing: the clouds. Several Spanish public agencies are collaborating on a research project, where cloudless images of a desired date are obtained by removing radiometric values of pixels with clouds and replacing with reflectance values that represent the existing land below the cloud. As well, it is possible to generate synthetic cloudless images of a desired date where there is any image capture by a satellite.

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