International Journal of Engineering Education Vol. 35, No. 3, pp. 912–924, 2019
Printed in Great Britain

0949-149X/91 $3.00+0.00

Astursat: A Software Tool to Encourage the Interest of Students in Remote Sensing and Image Processing*

LETICIA ALONSO-GONZÁLEZ[1], ANA ARBOLEYA[2] and FERNANDO LAS-HERAS[3]
[1,3] TSC-UNIOVI, Department of Electrical Engineering, University of Oviedo, Campus of Gijón, Ed. Polivalente. Gijón E-33203, Spain. E-mail: [1] leti.algo@gmail.com, [3] flasheras@uniovi.es
[2] Department of Signal Theory and Communications, University Rey Juan Carlos, Campus de Fuenlabrada, Ed. Departamental III. Fuenlabrada E-28943, Spain. E-mail: ana.arboleya@urjc.es

The purpose of this paper is to present and analyse the results, impact and scope achieved with Astursat, a software tool developed as a Final Degree Project in Telecommunication Engineering Masters' Studies. The aim of this tool is to encourage the interest of students in remote sensing and image processing. For this purpose, in-house meteorological and environmental raw data received at the Satellites Tracking Station installed at the University of Oviedo (Spain) is employed. With this data, a system with real functionality has been developed to foster professional skills. For this reason, Astursat represents the last logical block in a complex system composed of a remote sensing stage, a reception sub-system and the processing and visualisation of the corresponding information. Astursat has been designed in order to provide solutions for the shortages detected in similar commercial software packages. As an example, Astursat allows the possibility of defining a geographical region of interest where the images and animations can be focused on. Additionally, Astursat allows the generation of personalised combinations of different datasets from several instruments. Different processed images and video frames will be shown and discussed to illustrate the results achieved with the tool. An analysis of the impact of this project in Academia will be included.

Keywords: environmental; final degree project; image processing; meteorological; remote sensing; software; telecommunication engineering

1. Introduction

Image processing represents a major area of study with numerous direct applications in many different fields, from astronomy, to biotechnology or engineering, among others. However, in this paper, the focus is on decoding and processing meteorological and environmental data received from remote sensing satellites. Therefore, in this paper, a project called *Astursat*, which has been proposed as a Final Degree Project with the aim of promoting the interest in image processing and remote sensing of the Telecommunication Engineering students, is presented. The ideas which have led to the development of this project are described below.

The experience of the authors in teaching Telecommunication Engineering courses shows that the students pay more interest when the corresponding lesson is more related to a practical application. By doing this, the students can visualise from the beginning the purpose of the lesson. And, therefore, concepts, especially mathematical formulation, become easier to understand. Additionally, a practical application provides the possibility of simultaneously applying different concepts—even from different subjects—to solve a complete problem [1]. Consequently, when putting together and interrelating these different concepts, the students are provided with added learning value.

In order to put the latter into practice, the authors found very interesting to propose the implementation of a complete system for data acquisition and processing [2]. For this purpose, *Astursat*, framed in the context of the Satellites Tracking Station (STS) installed at the University of Oviedo, was proposed as a Final Degree Project with two different goals. First, *Astursat* was meant to be an application involving different topics, tangentially related to matters studied during the degree, although none of them are explicitly part of the degree syllabus, as happens with conventional projects [4]. For this reason, *Astursat* represented a challenge for a student, as he or she would have to deal with numerous bibliographical references to understand and interrelate the different concepts required to implement the tool. Meanwhile, the student would be completely involved in the fields of remote sensing and image processing, fostering his or her interest in these matters. This would develop different skills in the student such as self-motivation, organisation or autonomy. Secondly, *Astursat* would be of help to the faculty, as they could use it not only to explain concepts of remote sensing and image processing, but also to demonstrate what a student is able to do after studying the degree and, therefore, motivate new students to develop similar projects. Consequently, *Astursat*, together with the STS, provided a

* Accepted 20 February 2019.

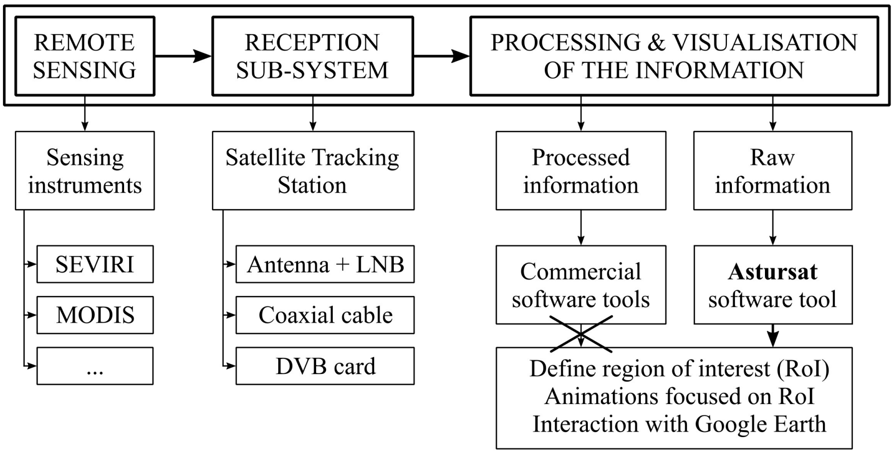


Fig. 1. Schematic of the complete system: Astursat and the STS within the context of a system for the acquisition, decoding and processing of real data.

complete system for demonstrating the acquisition, decoding and processing of real data, as schematically depicted in Fig. 1.

When *Astursat* and the origin of its data are explained to students of Telecommunication Engineering, they can identify concepts which have already been individually studied in different subjects. Moreover, they can find new concepts which, although beyond the scope of the syllabus, provide them with a wider knowledge of the Telecommunications Engineering field [5]. The *remote sensing* block in Fig. 1 represents a topic which is not explicitly included as a direct descriptor in the Telecommunications Master's degree syllabus, therefore, it is didactically explained to the students. The *reception sub-system* block represents the practical application of the theory which is studied in courses such as Antennas and Propagation or Transmission Systems. Analogously, the *processing and visualisation* block requires some of the concepts which are studied in Digital Signal Processing courses.

2. Earth observation and remote sensing overview

Environmental satellites provide a unique perspective for Earth observation. For this purpose, two different kinds of satellites are used, employing, respectively, geostationary or polar orbits. Geostationary satellites are placed in equatorial orbits at approximately 36,000 Km over the surface of the Earth. These satellites are very interesting in terms of remote sensing since they remain in the same relative position with respect to the Earth. In other words, they seem motionless when observed from the surface of the Earth. Consequently, their footprint or coverage is constant, and they provide information with a resolution of a few kilometres per pixel. Some of these geostationary satellites are from the Meteorological Satellite (Meteosat) [6, 7] or Geostationary Operational Environmental Satellite (GOES) [8, 9] series.

Alternatively, polar satellites are placed in orbits closer to the surface of the Earth, circumscribed in imaginary planes whose tilts are almost 90° (with respect to an Equatorial orbit). For this reason, these satellites do not remain in the same relative position with respect to the Earth and, therefore, their coverage areas are constantly varying. With orbit heights of approximately 800 Km, meteorological polar satellites provide information with higher resolution, around a few meters per pixel. Accordingly, a tracking system is required to follow the movement of these satellites and to point the antennas to receive their meteorological information which, for direct reception, is limited to the local coverage of the satellite for each ground station.

In order to understand the origin of the information provided by these satellites, basic concepts regarding remote sensing are required. Remote sensing means the acquisition of information, in a large scale, through different instruments (both passive and active) on-board satellites. These instruments must be sensitive to the electromagnetic radiation in different frequency bands. If the behaviour of the atmosphere is known for each frequency band, and the signal received in the satellite is analysed, then the meteorological and environmental information can be extracted. Radiation captured by satellites with passive instrumentation can have two different sources. On the one hand, this radiation can be emitted by the Earth and, therefore, belongs to the infra-red bands. On the other hand, the radiation can come from the Sun and be reflected in a body afterwards. This radiation belongs to the visible bands.

Once the information has been sensed and processed, an interpretation process is required. As an example, in a visible channel—a channel which has been measured using a frequency belonging to the range of visible bands—represented using a grayscale, the brightest parts of the image represent the seas and the oceans, while the darkest parts represent the surface of the Earth. However, the information provided by different channels can be combined and assigned to the RGB colours (red, green and blue), respectively, generating a false colour image which provides more information and can be easily interpreted.

3. Data reception at the satellites tracking station

Receiving information from the aforementioned types of satellites is meaningful in applications such as remote sensing, climate change or weather forecasting. However, in order to avoid the development of satellites with overlapping functionality by each country, different collaborative intergovernmental organisations have been created, as is the case of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) [10]. This organisation contributes with the EUMETCast broadcasting network [11], to GEONETCast [12], a global network of satellite-based data dissemination coordinated by the intergovernmental Group on Earth Observations (GEO) [13]. EUMETSAT exploits the satellites which belong to the Meteorological Satellite (Meteosat) [1] and the Meteorological Operational (MetOp) [14] series. The extracted meteorological and environmental information can be received at end-user stations using three alternatives: (1) from their online databases (not in real time, global coverage), (2) through direct data reception from each satellite providing coverage to the end-user ground station (real-time, local coverage) and (3) through the EUMETCast broadcasting channel (quasi-real time, global coverage) [15]. The latter is the alternative employed in *Astursat*, due to the high amount of available quasi-real time data; its operation is explained below.

The satellites from organisations belonging to EUMETSAT transmit their information to different ground stations all over the planet. From these ground stations, the information is sent to the EUMETSAT central station placed in Darmstadt (Germany), where it is compressed and codified. After this process, the information is sent through the EUMETCast channel to several geostationary satellites and globally broadcasted to the final user. In the particular case of Europe and, therefore, in the case of the STS at the University of Oviedo, the geostationary satellite from which the information is received is the Eutelsat-9 [16].

For this purpose, the University of Oviedo has the corresponding DVB (digital video broadcast) reception system on a balcony, as depicted in Fig. 2 This system is composed of a reflector antenna, a LNB (low noise block) operating in the Ku frequency band (12 GHz-18GHz) [17], provided with a down-converter (in order to down-convert and amplify the signal), and a coaxial cable to connect the LNB with a DVB card, to decode the data. The DVB card is connected to a working station placed at the STS, as depicted in Fig. 3.

Different types of data are received at the STS, such as processed products which can be visualised using commercial software, or low-level data which require subsequent processing techniques for their visualisation. The processed products are generated in meteorological data processing facilities called SAFs (Satellite Application Facilities), each one devoted to process specific data. The facilities from which the STS obtains data, and their most representative products are listed next:

- The Land Surface Analysis SAF (LSA SAF) [18], which provides information regarding the land surface temperature, albedo, vegetation, fires, snow covering, etc.
- The Ocean and Ice SAF (OSI SAF) [19], focusing mainly on sea ice oceans' temperature and radiative fluxes.
- The Meteorological Product Extraction Facility (MPEF) [20], specialised in data such as winds, clouds height and composition, radiances, global instability index of the air mass, ozone, humidity, volcanic ashes, etc.

Fig. 2. Antennas on the balcony at the University of Oviedo.

Fig. 3. Satellite Tracking Station (STS) at the University of Oviedo: computers for the data reception and processing and informative posters and monitors.

Apart from processed data and products, a large amount of raw data, directly extracted from the sensing instruments on-board the satellites, mainly Spinning Enhanced Visible and InfraRed Imager (SEVIRI) [21] and Moderate-Resolution Imaging Spectroradiometer (MODIS) [22] imagers, are sent within the EUMETCast data flow. Nevertheless, raw data require specific software tools for their decoding and processing and, for this purpose, *Astursat* has been developed.

4. Data processing and visualisation: comparison of available commercial software packages and *Astursat*

Several commercial tools have been previously developed to decode and visualise meteorological and environmental data and are available at the STS. As an example, the most remarkable tools from the *Satellite Processing Software* bundle of *Satsignal* [23] are essentially two. First, *MSG Data Manager*, which allows the user to decode and visualise information received from Meteosat satellites. This information can be represented as false colour images, which will be explained in detail along the subsequent sections. Second, *MSG Animator*, which allows the generation of videos in order to visualise the modifications of the represented parameters over time, after the information is decoded with the *MSG Data Manager*.

Nevertheless, *Astursat* goes one step forward and tries to solve some of the shortcomings present in commercial tools such as the *MSG Data Manager*. As an example, *Astursat* allows the possibility of defining a region of interest through the ranges of latitude and longitude. Moreover, *Astursat* allows the generation of animations based on time-lapses, although focused in the predefined region of interest. This facilitates the visualisation and explanation of different phenomena such as the motion of

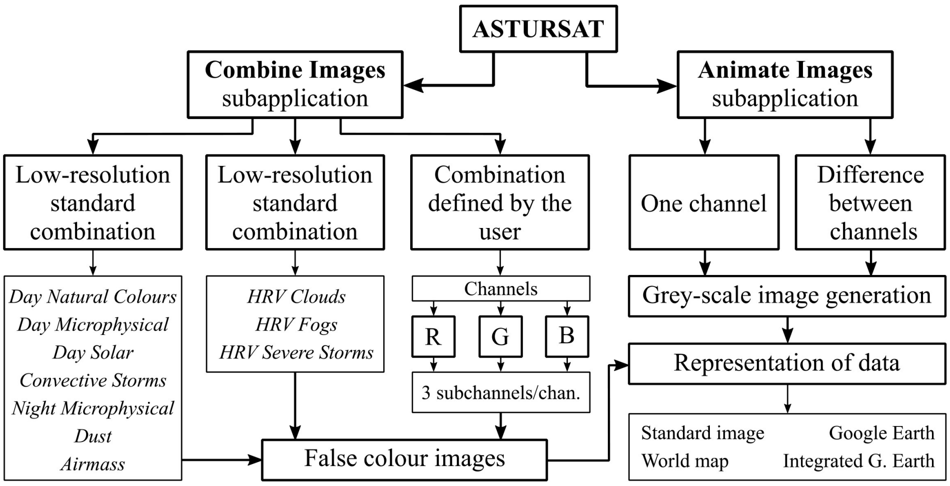
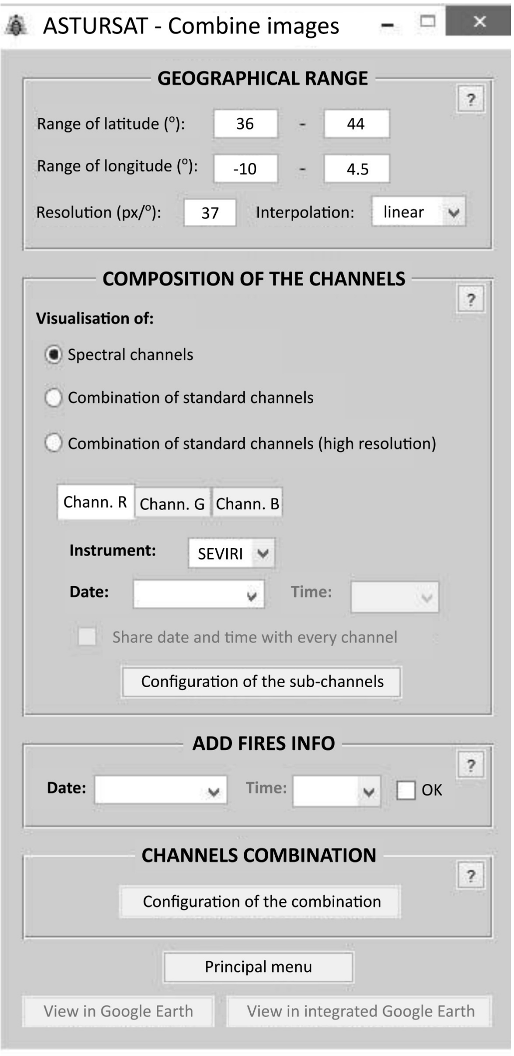


Fig. 4. Schematic of the complete tool: block diagram of both subapplications.

Fig. 5. Menu of the main application of Astursat where the user can select the sub-application to use.

the clouds. Consequently, as the information is focused on the región of interest, the processing time is reduced. Moreover, *Astursat* interacts with well-known applications such as Google Earth [24] and allows representing its own results over the maps provided by Google Earth. As a result, the functionalities provided by Google Earth can be employed in the results generated using *Astursat* in two different ways: Google Earth data can be visualised in a simplified integrated display within the *Astursat* application denoted *Integrated Google Earth*, or directly in the Google Earth application.



Range of latitude (°): 36 - 44

Range of longitude (°): -10 - 4.5

Resolution (px/°): 37 Interpolation: linear

Visualisation of:

● Spectral channels

○ Combination of standard channels

○ Combination of standard channels (high resolution)

Chann. R Chann. G Chann. B

Instrument: SEVIRI

Date: Time:

☐ Share date and time with every channel

Date: Time: ☐ OK

Fig. 6. *Combine Images* sub-application menu: allows the user to select the geographical range to study, specify the type of visualisation and the corresponding channels, add information about the fires and proceed with the configuration of the combination.

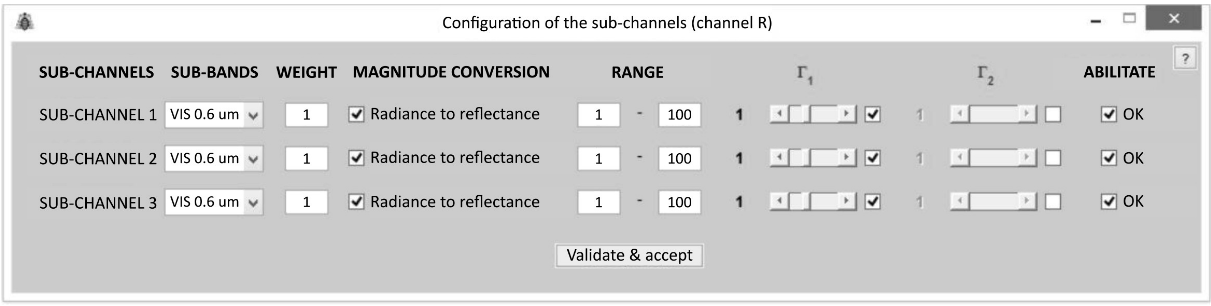
As mentioned before, *Astursat* can process raw or level 1b data from the twelve different channels or spectral bands of the SEVIRI instrument, as well as data for the monitorisation of fires and extremely high temperature areas on Earth. Additionally, MODIS thirty-six spectral bands raw data processing functionalities were added during the development of another Final Degree Project [25]. This large number of channels allows combinations in multiple ways. Furthermore, RGB filters can be assigned to those combinations so that different phenomena can be enhanced. As an example, standard combinations allow the visualisation of the following parameters: day natural colours, microphysical parameters, air masses, dust, clouds height and type, fog, severe storms, aerosols, phytoplankton and biochemistry of the ocean, temperature of the ocean, lands and clouds, ozone, fires etc.

5. *Astursat* software tool

Astursat is implemented using MATLAB [26] and is composed of two different sub-applications, denoted *Combine Images* and *Animate Images*, and devoted to the representation of images and the creation of time-lapses, respectively. A schematic representation of the complete tool is depicted in Fig. 4. Each sub-application can be accessed from the principal menu of the main application represented in Fig. 5. In the following two subsections, each sub-application will be described.

5.1 'Combine Images' sub-application

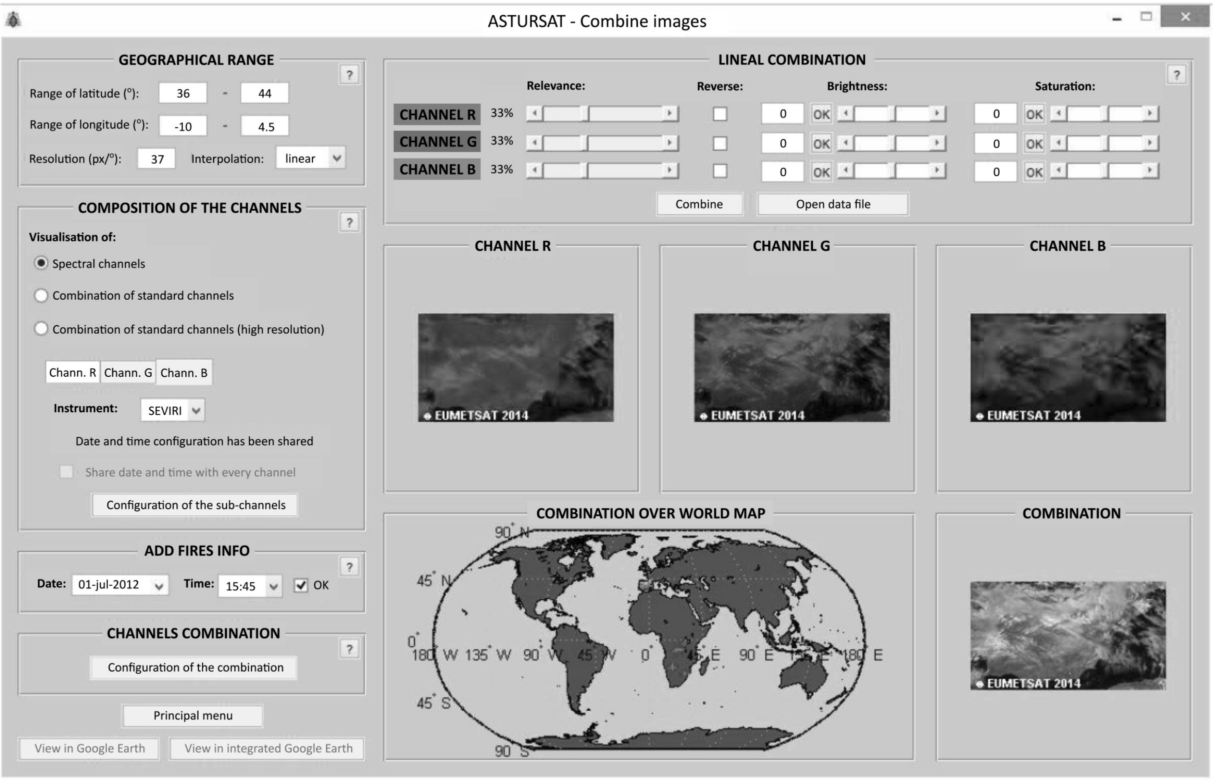
Once the user has selected the *Combine Images* sub-application, a new graphical user interface (GUI), divided into four configuration panels, appears in a different window as shown in Fig. 6, and the geographical region of interest can be defined to focus the processed data on a certain region. Once



Configuration of the sub-channels (channel R)

SUB-CHANNELS	SUB-BANDS	WEIGHT	MAGNITUDE CONVERSION	RANGE	Γ_1	Γ_2	ABILITATE
SUB-CHANNEL 1	VIS 0.6 um	1	☑ Radiance to reflectance	1 - 100	1 ☑	1 ☐	☑ OK
SUB-CHANNEL 2	VIS 0.6 um	1	☑ Radiance to reflectance	1 - 100	1 ☑	1 ☐	☑ OK
SUB-CHANNEL 3	VIS 0.6 um	1	☑ Radiance to reflectance	1 - 100	1 ☑	1 ☐	☑ OK

Fig. 7. Configuration of the sub-channels: allows the user to select and configure three sub-channels to be used in one of the RGB channels.



ASTURSAT - Combine images

GEOGRAPHICAL RANGE

Range of latitude (°): 36 - 44

Range of longitude (°): -10 - 4.5

Resolution (px/°): 37 Interpolation: linear

COMPOSITION OF THE CHANNELS

Visualisation of:

● Spectral channels

○ Combination of standard channels

○ Combination of standard channels (high resolution)

Instrument: SEVIRI

Date and time configuration has been shared

☐ Share date and time with every channel

ADD FIRES INFO

Date: 01-jul-2012 Time: 15:45 ☑ OK

CHANNELS COMBINATION

LINEAL COMBINATION

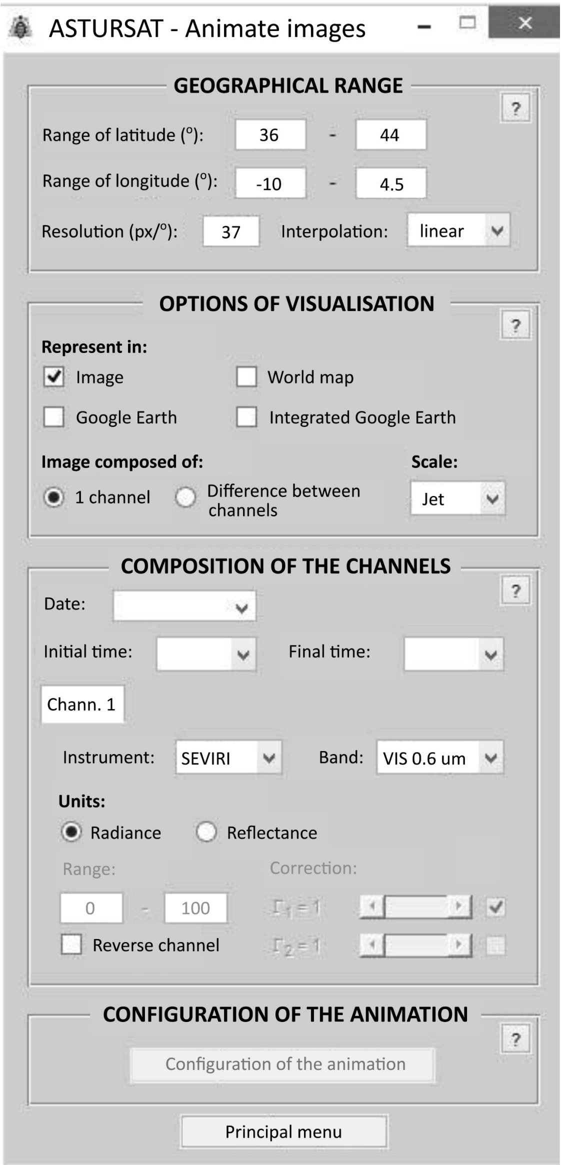
	Relevance:	Reverse:	Brightness:		Saturation:	
CHANNEL R	33%	☐	0	OK	0	OK
CHANNEL G	33%	☐	0	OK	0	OK
CHANNEL B	33%	☐	0	OK	0	OK

Fig. 8. Extended GUI for *Combine Images* and results: allows the user to configure the parameters of the linear combination of channels and shows the representation of the individual channels in the selected geographical range, and the corresponding false image and its location in a world map.

the region of interest is defined, the type of data to represent can be selected between the following options: spectral channels, combination of standard channels or the analogous combination using high resolution data. The information provided by each of these channels has been sensed using an instrument, such as the SEVIRI [21], and can be represented as RGB components. Three or more channels can be then configured [27], as depicted in Fig. 7, and combined to compose a false colour image. Additionally, information regarding fires or very hot regions [28] can be processed and superposed over the meteorological data to provide the final image with more information. Partial results are depicted in Fig. 8, where the different representations of the false colour images can be identified: the RGB independent components, the resultant image over a world map together with the points where a fire was detected, or the false colour image. The images can be enlarged by clicking on them.

5.2 *'Animate Images' sub-application*

If the user has selected the *Animate Images* sub-application, a different GUI appears in a new window, as shown in Fig. 9. As it happens with the *Combine Images* sub-application, the first panel is devoted to the configuration of the geographical



Range of latitude (°): 36 - 44
Range of longitude (°): -10 - 4.5
Resolution (px/°): 37 Interpolation: linear

Represent in:
☑ Image ☐ World map
☐ Google Earth ☐ Integrated Google Earth

Image composed of: ● 1 channel ○ Difference between channels
Scale: Jet

Date:
Initial time: Final time:
Chann. 1
Instrument: SEVIRI Band: VIS 0.6 um
Units: ● Radiance ○ Reflectance
Range: 0 - 100
Correction: $\Gamma_1 = 1$ ☑ $\Gamma_2 = 1$ ☐
☐ Reverse channel

Fig. 9. *Animate Images* sub-application menu: allows the user to select the geographical range to study, specify the types of visualisation, the date and the initial and final times to generate the time-lapse, as well as the units.

range. Then, the user can select the type of representation to be used for the time-lapse. In order to compose the animation, the dates and times corresponding to the initial and final frames must be indicated. Each frame corresponds to a spectral band sensed by an instrument and can be configured. Partial results are represented in Fig. 10. In the top of the extended GUI, the user can configure the parameters of the animation, such as the format of the output video, type of compression or number of frames per second, among others. Once the video is generated, it is displayed in a video player integrated in the GUI. In order to interpret the colours of the represented data, the corresponding legend is represented in the right part of the extended GUI.

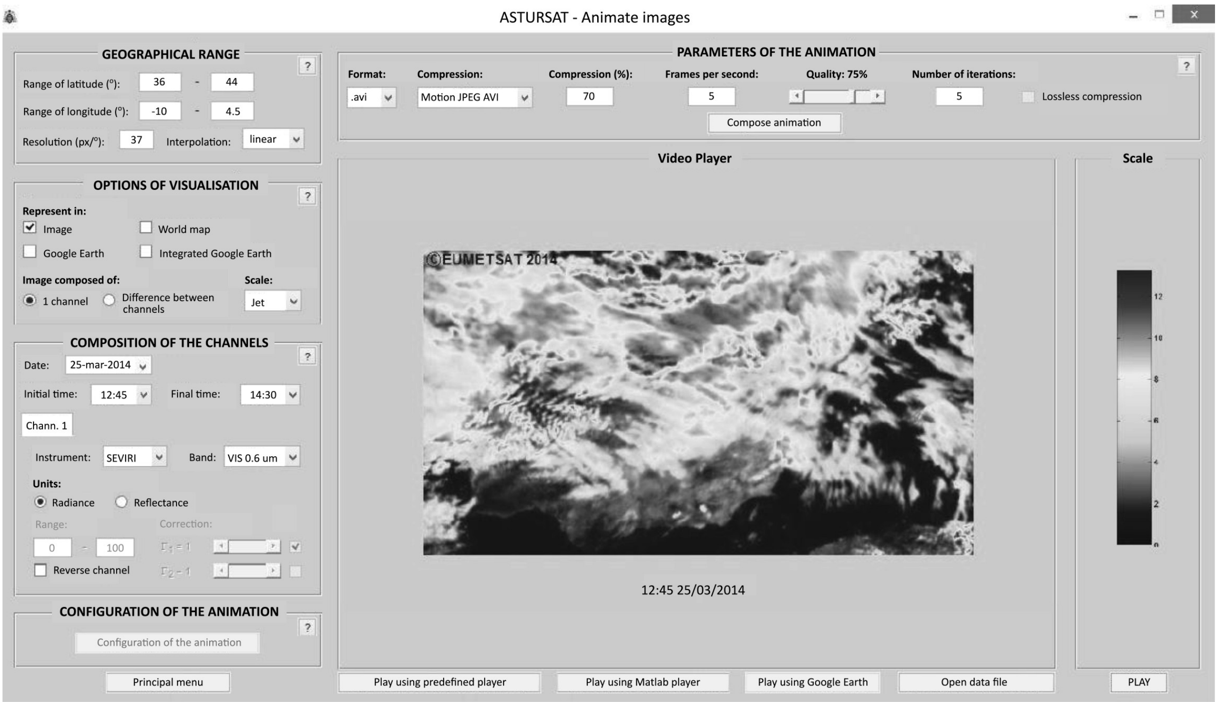
6. Results: processed data and interpretation

In this section, some significant results obtained with *Astursat* are presented to demonstrate its functionality. First, the standard combination denoted *HRV Fogs* (using the high-resolution version of 37 pixels per degree) is represented in Fig. 11 and applied to a geographical range circumscribed to latitudes and longitudes from 30° to 60° and from –10° to 25°, respectively, which corresponds to middle Europe and the north of Africa. The results are presented in an independent conventional image which can be magnified. This standard combination is composed of three channels, the near-infrared whose central wavelength is 1.6 μm (NIR1.6) and twice the high-resolution visible (HRV), assigned to the RGB components, respectively, as summarised in Table 1. Thanks to this combination, the difference between the fog or the low clouds and the snow-covered land can be discriminated. Besides, as the ice and the water cloud appear in different colours, they can be distinguished. Nevertheless, as the combination is realised using at least one visible channel, it only works with daytime data acquisitions.

Second, an example of the fire representation is depicted in Fig. 12. In this case, coordinates corresponding to fires and very hot points over the surface of the Earth (as partially extinguished fires or volcanos about to erupt) have been processed. A fire symbol has been superposed on those coordinates over a Google Earth platform integrated in the *Astursat* GUI. This example has been circumscribed to the fires localised in the Democratic Republic of the Congo, Rwanda, Tanzania and Kenya, since

Table 1. Summarised information regarding the "HRV Fog" combination

Colour	Channel	Physically relates to	Small contribution to the signal of	Large contribution to the signal of
Red	NIR1.6	Cloud phase Snow reflectivity	Ice cloud Snow covered land	Water clouds
Green	HRV	Cloud optical thickness Snow reflectivity	Thin clouds	Thick clouds Snow covered land
Blue	HRV	Cloud optical thickness Snow reflectivity	Thin clouds	Thick clouds Snow covered land



Range of latitude (°): 36 - 44
Range of longitude (°): -10 - 4.5
Resolution (px/°): 37
Interpolation: linear

Represent in:
☑ Image
☐ World map
☐ Google Earth
☐ Integrated Google Earth

Image composed of:
● 1 channel
○ Difference between channels

Scale: Jet

Date: 25-mar-2014
Initial time: 12:45
Final time: 14:30
Chann. 1
Instrument: SEVIRI
Band: VIS 0.6 um

Units:
● Radiance
○ Reflectance

Range: 0 - 100
Correction:
$\Gamma_1 = 1$ ☑
$\Gamma_2 = 1$ ☐
☐ Reverse channel

Format: .avi
Compression: Motion JPEG AVI
Compression (%): 70
Frames per second: 5
Quality: 75%
Number of iterations: 5
☐ Lossless compression

12:45 25/03/2014

Fig. 10. Extended GUI for *Animate Images* and results: allows the user to configure the parameters of the animation and shows the video player for the time-lapse and the corresponding scale.

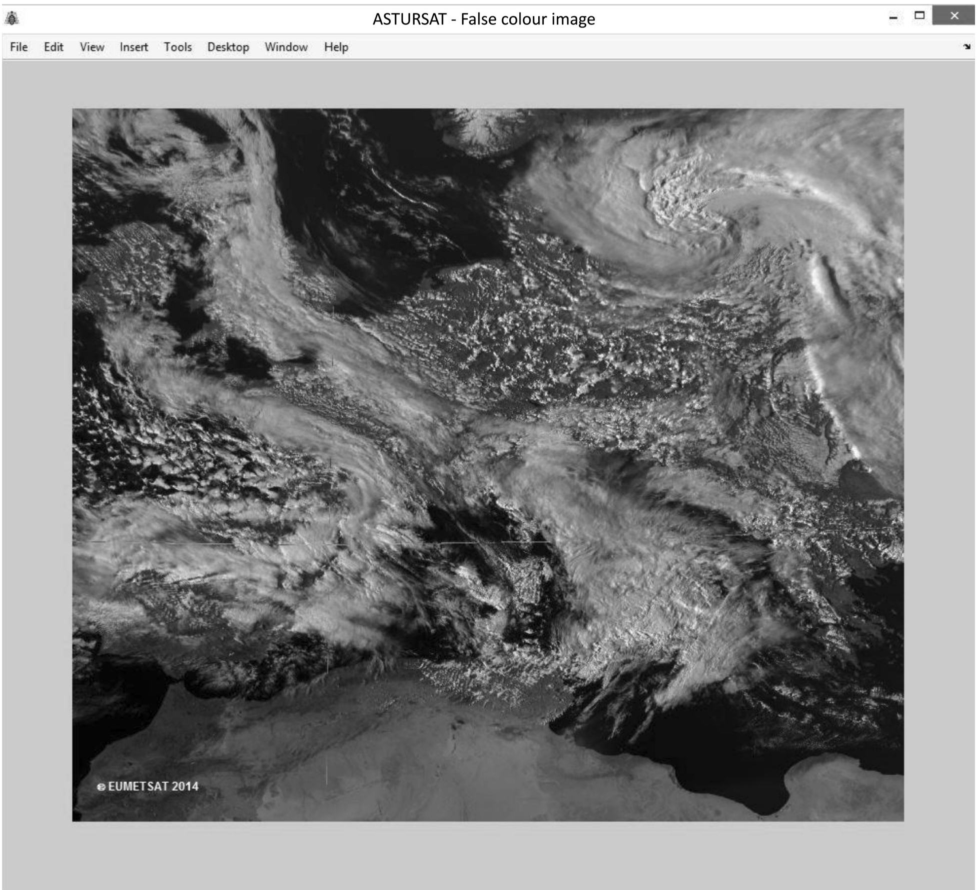


Fig. 11. Detailed example of a resulting false colour image in Europe using the high-resolution standard combination “HRV Fogs” (March, 25th 2014 at 15:00 GMT).

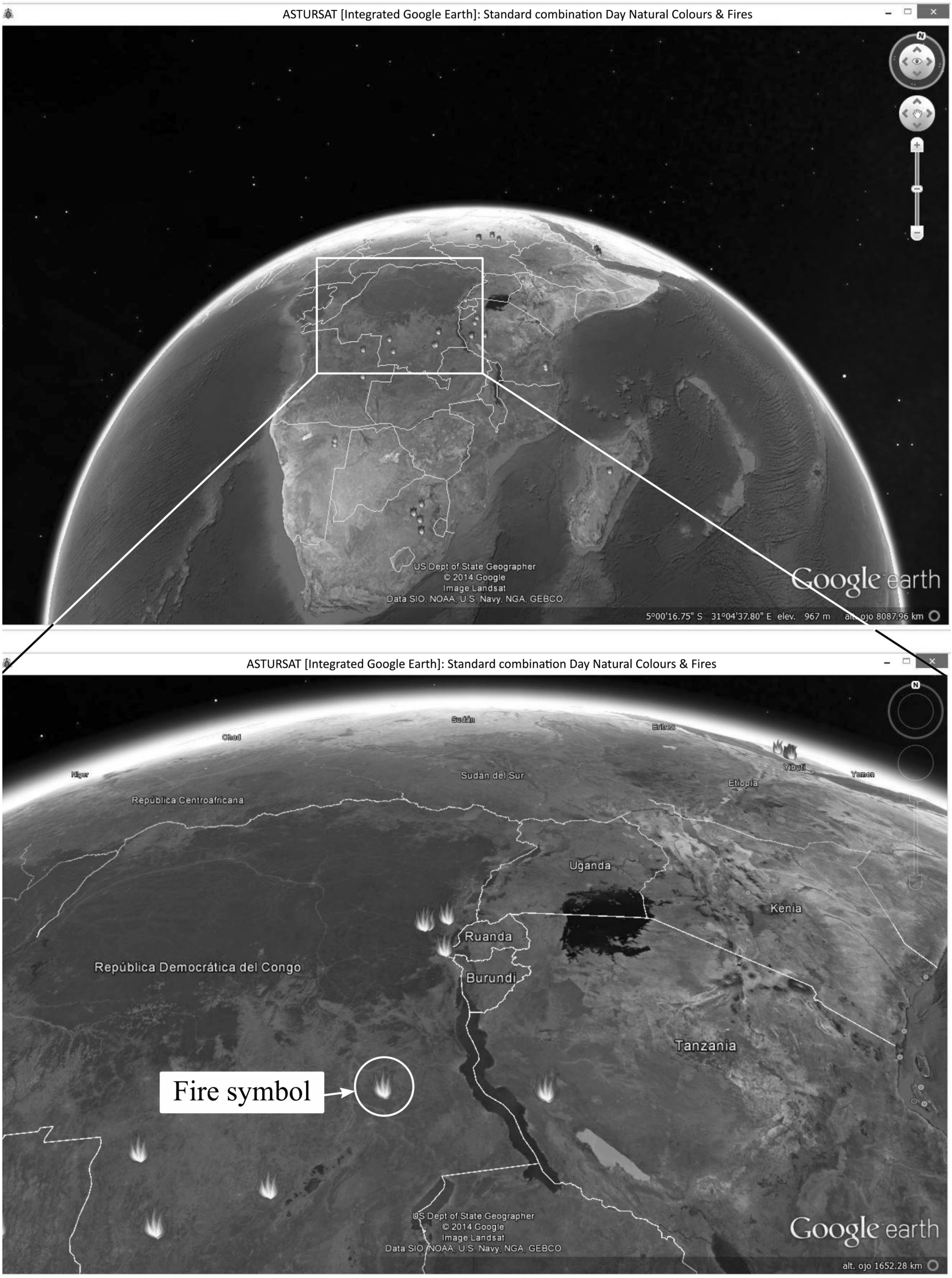


Fig. 12. Example of the representation of fires in Africa and the corresponding magnification in the north of Africa (May, 1st 2012 at 02:00 GMT).

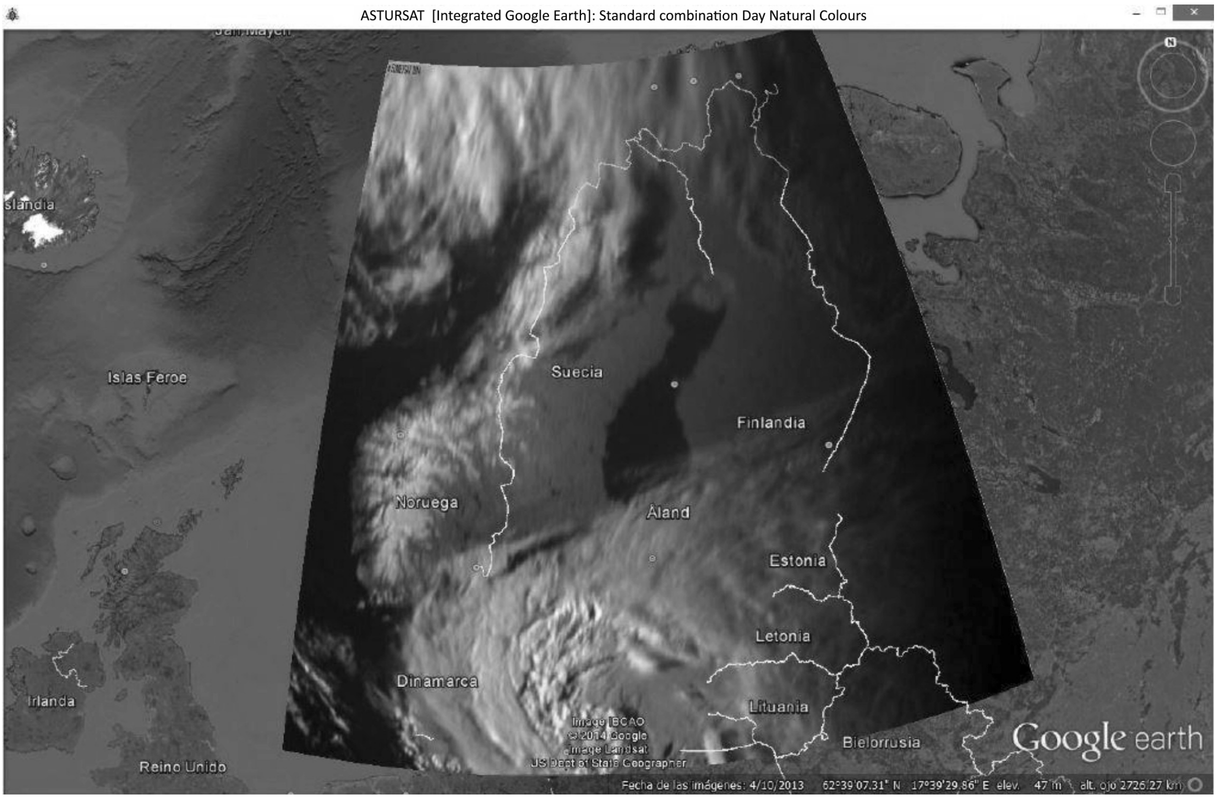


Fig. 13. Resulting standard combination *Day Natural Colours* using the integrated Google Earth interface, corresponding to a geographical range which includes the Nordic countries (March, 23rd 2014 at 12:45 GMT).

when the data were acquired, several fires took place in those regions. Although it is not the case in this example, fire information can be overlapped with images obtained from any channel combination (see Section 5.1).

The last example corresponds to a standard combination denoted *Day Natural Colours* (using, again, the high-resolution data), as depicted in Fig. 13. This representation shows the information in a geographical range circumscribed to latitudes and longitudes from 59° to 72° and from 20° to 32°, respectively, which corresponds to the European Nordic countries. This standard combination is generated assigning the near infrared channel (NIR1.6) and the visible channels whose central wavelengths are 0.8 μm (VIS0.8) and 0.6 μm (VIS0.6) respectively to the RGB components, as summarised in Table 2. With this combination, the surface characteristics such as snow coverage, vegetation or bare soil, can be clearly distinguished in the false colour image. The *Day Natural Colours* combination can only be used with data acquired during the daytime, as it uses visible channels. This phenomenon can be seen using the *Animate images* sub-application and selecting a time-lapse corresponding to a complete day. At night, the complete image becomes dark and no information is represented. In order to obtain meteorological information during night-time, thermal (infrared) channels must be used, as their information is provided by the radiation emitted from the Earth.

Table 2. Summarised information regarding the "Day Natural Colours" combination

Colour	Channel	Physically relates to	Small contribution to the signal of	Large contribution to the signal of
Red	NIR1.6	Cloud phase Snow reflectivity	Ice cloud Snow covered land	Water clouds
Green	VIS0.8	Cloud optical thickness Green vegetation	Thin clouds	Thick clouds Snow covered land Vegetation
Blue	VIS0.6	Cloud optical thickness Green vegetation	Thin clouds Vegetation	Thick clouds Snow covered land Sea ice

7. Impact in academia

Astursat has been conceived from the beginning as a different Final Degree Project in Telecommunication Engineering in comparison to the conventional ones. In other words, students normally tend to focus on a topic they are interested in, which has already been studied during the degree up to some extent, and develop their Final Degree Projects, starting from some basic ideas and following a guideline proposed by the supervisors. However, projects like *Astursat* represent a challenge for students, as all the topics involved are tangentially related to the degree, although none of them have been explicitly studied during the degree. This makes the student begin from the scratch, decide the matters to study, and conceive their own guideline to achieve the final goal. This process provides the student with numerous skills such as organisation, scientific curiosity, autonomy, research and know how to discriminate between useful and non-useful information, among others.

Implementing *Astursat* not only deals with processing complex data and designing a useful GUI. Understanding how data are obtained and the significance of the multi-spectral combination of channels is also fundamental to generate and interpret correctly the results. For this purpose, the student needs to thoroughly study the state-of-the-art in remote sensing and the documentation provided by EUMETSAT. This documentation is of great interest, as it explains straight to the point how each combination of data is generated and why each channel is selected.

The more documented the student is, the more functionalities the student can implement to make *Astursat* a more useful tool. Therefore, *Astursat* makes the students understand that remote sensing is an application completely related to telecommunications engineering with a high relevance in quotidian topics like the weather forecast and the analysis of crucial matters such as climate change. Consequently, understanding how meteorological images are generated and their numerous applications, encourages the students interest in remote sensing.

Astursat, in the context of the STS at the University of Oviedo, represents one of the key tools for demonstration in the dissemination activities. The students have the opportunity to participate, voluntarily, in dissemination activities to other students and the general public in open days or in various activities of the national event “the Week of Science”. In this event different activities take place to show scientific experiments or tools for demonstrations in order to bring science closer to the public. Thanks to *Astursat*, the experience in these events highlights the commitment reached by the student with the project and considerably increases the interest of other engineering students in the realization of projects related to satellites, imaging or remote sensing topics. This kind of activity is fundamental from the point of view of learning how to divulge one’s own work, as it develops transversal skills such as synthesis capacity and public communication.

It is also important to remember that *Astursat* is a software tool which was developed as a Final Degree Project in Telecommunication Engineering and, consequently, it was evaluated by an examining board composed of experts in the field and the project was given the highest marks (with honours). Besides, this project was also recognised in two contests: (a) *Astursat* was considered the best final project from the *Gijón Technical Engineering School Partners Society*, sponsored by *Indra Software Labs*; (b) *Astursat* was considered the best project in satellite services by the *Professional Association of Telecommunication Engineers at Spain—Hisdesat Award*. These outstanding evaluations from different examining boards also encouraged other students to develop similar challenging projects. Consequently, *Astursat* project did not finish after its evaluation. The immediate ideas for its enhancement were, on the one hand, increasing the number of different data files to process and represent with the *Astursat* and, on the other hand, improving the application response velocity using graphics processing units (GPU). These two improvements were implemented in another Final Degree Project [25]. Additionally, an antenna tracking system for polar satellites real-time reception was implemented to provide the STS with a complete functionality to receive data from multiple sources and their subsequent visualisation using commercial software tools. In order to take advantage of this new system and improve *Astursat* in the future, not only processed data should be received from the polar satellites, but also raw data to process with *Astursat*. If raw data from the polar satellites were received and processed with *Astursat*, the differences between the information provided by geostationary and polar satellites could be analysed, making *Astursat* a more useful geographic information system (GIS) for education purposes.

In short, from the academic point of view, the impact of *Astursat* is twofold. On the one hand, regarding the students involved in this type of projects and, particularly, in *Astursat*, they deal with their first and most related to a real job experience, which supposes a great challenge. They learn how to find a technical solution to a real and complex problem, which is the processing and representation of meteorological data. To do this, the students must deal with scientific papers, numerous bibliographical resources, and documentation from EUMETSAT, developing research and analysis skills, as well as increasing their interest in remote sensing and image processing. As these matters have not been studied during the degree, this process provides the student with autonomy and organisation skills. Although this type of projects is meant to be developed almost autonomously, if the student gets lost, he or she receives help or feedback from the supervisors. Additionally, the student has the opportunity to divulge his or her own work in dissemination activities in order to capture the interest of other students to develop projects like *Astursat*, while improving essential skills such as public communication. On the other hand, tools for demonstration, such as *Astursat*, developed by students, are very useful for the faculties. They can use *Astursat* not only as a support tool to explain remote sensing or image processing, but also to show what former students have been able to develop and, consequently, motivate new students.

8. Conclusions

In the area of Signal Theory and Communications at the University of Oviedo there is a great expertise in imaging techniques and antenna systems, and therefore, with the aim of drawing the students' attention and allow them to work in transversal branches, not included in the syllabus, and to develop professional skills, the idea of proposing alternative projects arose. These Final Degree Projects, like *Astursat*, have led to an increase in the motivation and involvement of the students in their realization. This conclusion is the result of an increase in the number of requests from the students to develop this type of projects, from which they can learn different matters which have not been previously studied during the degree, achieving numerous and useful skills.

Taking the advantage of having the STS already installed at the University of Oviedo, a project which could increase its functionality, while involving additional complexity in comparison to conventional Final Degree Projects, seemed an interesting idea. For this purpose, and with the aim of overcoming some drawbacks present in the software tools already installed in the STS, the idea of *Astursat* emerged. From the beginning, *Astursat* supposed a challenge to the student due to the necessity of consulting numerous bibliographical resources regarding the techniques to decode and post-process the data. Despite the complexity of the project, the involved student always felt motivated since, from the beginning, the student knew the high applicability of the project and was free to include as many additional functionalities to the tool as desired. Finally, the student developed a software tool which was given the highest marks and the project was recognised in two contests. Thanks to this Project, the student could develop different skills such as working autonomously, proposing new ideas or learning how to divulge her own work during the dissemination activities. Additionally, apart from being a GIS to illustrate a remote sensing and image processing application, this tool is useful for the faculties to demonstrate what former students could develop, motivating new students to get involved in this type of projects.

In addition to this project, other two complementary projects, related to the STS were proposed, following the same idea of alternative Final Degree Projects. In all of these cases, the quality of the work done and the commitment of the students was above that normally observed in Final Degree Projects. Their commitment and the standard of their project work helped them to find employment after they had finished their degree. Thus, it can be concluded that this type of projects, with clear applicability, help to motivate students to overcome the difficulties related to the complexity of the topic and emphasize transversal competences, key to a successful differentiation in their access to the job market.

Acknowledgment—This research was partially funded by the Government of the Principality of Asturias (PCTI) and European Union (FEDER) under grant IDI/2018/000191.

References

1. B. Johnson and R. Ulseth, Student Experience for the Development of Professional Competences in a Project-Based Learning Curriculum, *International Journal of Engineering and Education*, **33**, pp. 1031–1047, 2017.
2. E. Peña, D. Fonseca, N. Marti and J. Ferrandiz, Relationship between specific professional competences and learning activities of the building and construction Engineering degree final project, *International Journal of Engineering Education*, **34**(3), pp. 924–939, 2018.
3. Leticia Alonso González, *Astursat: Application for processing and visualization of environmental data received in the Satellites Tracking Station of the University of Oviedo*, Final Degree Project, University of Oviedo, Spain, July 2014.
4. R. A. Hart and T. W. Polk, An Examination of the Factors that Influence Students' Capstone Project Choices, *International Journal of Engineering and Education*, **33**, pp. 1422–1431, 2017.
5. F. Sánchez, J. Climent, J. Corbalán, P. Fonseca, J. García, J. Herrero, H. Rodríguez and M. Sancho, A proposal to develop and assess professional skills in Engineering Final Year Projects, *International Journal of Engineering Education*, **34**(2A), pp. 400–413, 2018.
6. EUMETSAT, Meteosat Second Generation, https://www.eumetsat.int/website/home/satellites/currentsatellites/meteosat/index.html (retrieved August 2018).
7. W. Schumann, P. Mauté and A. Lanothe, Meteosat Second Generation: MSG1 Performances and MSG Future, *55th International Astronautical Congress of the International Astronautical Federation, the International Academy of Astronautics, and the International Institute of Space Law, International Astronautical Congress (IAF)*, Vancouver, British Columbia, Canada, 4–8 Oct., 2004.

8. NASA, GOES Overview and History, https://www.nasa.gov/content/goes-overview/index.html (retrieved August 2018).
9. M. A. Lombardi and D. W. Hanson, The GOES Time Code Service, 1974–2004: A Retrospective, *Journal of Research of the National Institutes of Standards and Technology*, **110**(2) pp. 79–96, 2005.
10. EUMETSAT, Monitoring Weather and Climate From Space, Home page, https://www.eumetsat.int/website/home/index.html (retrieved August 2018).
11. EUM TD 15 (2004): EUMETCast, EUMETSAT's Broadcast System for Environmental Data. Technical description, Issue 3.2, 5 September, 2004. EUMETSAT, Darmstadt, Germany.
12. EUMETSAT, GEONETCast is a global network of satellite-based data dissemination systems providing environmental data to a world-wide user community, https://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/GEONETCast/index.html (retrieved August 2018).
13. Group on Earth Observations, GEOSS Portal Home Page, https://www.earthobservations.org/index2.php (retrieved August 2018).
14. EUMETSAT, MetOp satellite series, https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Metop/index.html (retrieved August 2018).
15. EUMETSAT, EUMETCast: EUMETSAT's primary dissemination mechanism for the near real-time delivery of satellite data and products, https://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html (retrieved August 2018).
16. Eutelsat, Eutelsat-9B, 9° East, https://www.eutelsat.com/home/satellites/the-fleet/9-east.html (retrieved August 2018).
17. IEEE Standard Letter Designations for Radar-Frequency Bands, in *IEEE Std 521-1976*, pp. 1–8, 30 Nov. 1976.
18. Land SAF, Land and Surface Analysis Facilities, https://landsaf.ipma.pt/en/ (retrieved August 2018).
19. OSI SAF, OSI-SAF, Ocean and Ice Analysis Facilities, http://www.osi-saf.org/ (retrieved August 2018).
20. EUMETSAT, Meteorological Product Extraction Facilities, https://www.eumetsat.int/website/home/News/DAT_3559394.html (retrieved August 2018).
21. D.M.A. Aminou, MSG's SEVIRI Instrument, ESA bulletin 111, chapter 4, August 2002.
22. NASA, MODIS: Moderate Resolution Imaging Sprectroradiometer, https://modis.gsfc.nasa.gov/about/ (retrieved August 2018).
23. Satsignal Weather Satellite Tools Bundle, https://www.satsignal.eu/software/wxsat.htm (retrieved August 2018)
24. Google Inc. (2009). Google Earth release 5.1 [Software]. https://www.google.com/earth/ (retrieved August 2018).
25. Carla Morán Guizán, Processing and Graphical Integration of Meteorological and Environmental Multi-Satellite Data, Bachelor's Final Degree Project, University of Oviedo, Spain, 2014.
26. The Mathworks, Inc. (2014) MatLab release 14 [Software] https://es.mathworks.com/ (retrieved August 2018).
27. W. Burger, M. J, Burge, *Principles of Digital Image Processing: Fundamental Techniques*, Springer Science & Business Media, 2010.
28. EUMETSAT, Use of Seviri and AVHRR channels for remote fire/smoke detection, https://www.eumetsat.int/website/home/Data/Training/TrainingLibrary/DAT_2042930.html (retrieved August 2018).
29. Pablo Fernández Alonso, Design and implementation of satellite tracking functionalities for the Satellite Tracking Station at the University of Oviedo, Bachelor's Final Degree Project, University of Oviedo, Spain, 2014.

Leticia Alonso-González received the MSc degree in telecommunications engineering from the University of Oviedo, Gijón, Spain, the MSc degree in Systems and Control Engineering from the National University of Distance Learning (UNED) and Universidad Complutense de Madrid, Spain, and the PhD degree at the University of Oviedo, Spain, in 2014, 2018 and 2018, respectively. Since 2014, she has been working as a researcher in the Signal Theory and Communications Group, University of Oviedo. She was a Visiting Scholar at the George Green Institute for Electromagnetics Research at the University of Nottingham (UK) in 2017. Her main research effort is focused on the design, simulation and manufacturing techniques to develop microwave and millimetre-wave passive circuits and antennas fully integrated in textile technology.

Ana Arboleya received the MSc degree in telecommunication engineering in 2009 and the PhD degree in telecommunication engineering in 2016 from the University of Oviedo, Spain. From 2008 to 2016, she worked as a research assistant within the Signal Theory and Communications research group, TSC-UNIOVI, at the Department of Electrical Engineering in the University of Oviedo. During 2017 she held a postdoc position in the EpOC Polytech' Lab (Electronics for Connected Objects) of the University of Nice-Sophia Antipolis, France. At present she is an assistant professor in Universidad Rey Juan Carlos, Madrid, Spain. She was a Visiting Scholar in 2014 and 2015 in the Department of Radio Science and Engineering and MilliLab, in Aalto University, Finland. Her major research interests comprise antenna diagnostics and measurement systems and techniques, and high frequency imaging techniques and applications. Dr. Arboleya was the recipient of the 2017 National Awards of the Official College of Telecommunication Engineers of Spain to the Best PhD Thesis on Telecommunication Engineering in the category of security and defense.

Fernando Las-Heras received the MS and PhD degrees in telecommunication engineering from the Technical University of Madrid (UPM), Madrid, Spain, in 1987 and 1990, respectively. He was a National Graduate Research Fellow from 1988 to 1990 and an Associate Professor from 1991 to 2000 with the Department of Signal, Systems and Radiocom, UPM. He was the Vice-Dean of Telecommunication Engineering with the Technical School of Engineering, Gijón, from 2004 to 2008. He was a Visiting Researcher with Syracuse University, New York, NY, USA, and a Visiting Lecturer with the National University of Engineering, Lima, Peru, and the École Supérieure d'Ingénieurs en Génie Électrique, Rouen, France. He has been the Head with the Signal Theory and Communications Research Group, Department of Electrical Engineering, University of Oviedo, Gijón, Spain, since 2001, and has been a Full Professor since 2003. He has authored over 450 technical journal and conference papers in the areas of electromagnetic radiation, propagation and scattering theory and applications as well as inverse problems. Dr. Las-Heras held the Telefónica Chair on "RF Technologies, ICTs Applied to Environment and Climate Change", and ICTs and Smartcities, from 2005 to 2015. He was a member of the Board of Directors of the IEEE Spain Section from 2012 to 2015, and a member of the Science, Technology and Innovation Council of Asturias, Spain, in 2010. He is a member of the IEEE Microwaves and Antennas Propagation Chapter (AP03/MTT17) Board from 2016 to 2018.