# A STEP BEYOND VISUALIZATION: HOW TO INGEST METEOSAT SECOND GENERATION SATELLITE DATA AND PRODUCTS INTO McIDAS-V, ILWIS AND TerraMA[2]

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**Abstract**

The Laboratory for Analyzing and Processing Satellite Images (LAPIS) of the University of Alagoas (UFAL) has been very active in the usage of Meteosat Second Generation (MSG) satellite data and products since 2007. These data and products are received in near-real time using simple and low cost ground reception infrastructure. Several examples of the ingest and display process for MSG satellite data and products are presented. The ingest of these satellite data and products is accomplished using a McIDAS-V, ILWIS and TerraMA[2] tools. It is also shown how these MSG satellite-based products can be combined with other data. Results show that McIDAS-V, ILWIS and TerraMA[2] are very useful tools to researchers and forecasters in the input and display process for MSG satellite data and products.

**Keywords:** Open Source Software, EUMETCast, Meteosat.

## 1. Introduction

With the drastic advances in technology over the past decades, the availability, as well as the quantity, of large data sets for research in almost every scientific field has increased dramatically (e.g. Kehrer, 2011; Nocke *et al.* 2008). More specifically, the availability of earth observation-based imagery data and satellite information for research purposes and practical applications has grown with many organizations such as the European Organisation for the Exploitation

of Meteorological Satellites (EUMETSAT), the National Aeronautics Space Administration (NASA), the National Oceanic and Atmospheric administration (NOAA), etc. For instance, through GEONETCast systems(EUMETCast, GEONETCast Américas and CMACast), which are part of the core Global Earth Observation System of Systems (GEOSS), the users do not need to repeatedly build ground receiving stations for different satellites (Wolf and Williams, 2007). The additional importance of GEONETCast systems is that they provide the measurements, and products for validating the prediction methodology (non-real-time), and for verifying the forecasts (near-real-time), including both the guidance, and the actual forecasts and warnings (Barbosa, 2013).

Observations from satellites are now providing quantitative information about how the Earth system varies on a variety of spatial and temporal time scales, documenting longer-term evolution, and providing information that can inform prediction and enable better policy and management decisions (Barbosa and Kumar, 2012). Satellite-based data help improve understanding not only of how individual Earth system components (atmosphere, biosphere, cryosphere, ocean, Earth surface) evolve but how they interact with each other and both contribute and respond to naturally-occurring and human induced change (UNEP, 2008). As well, diagnostic products (multi-channel based), and color enhanced images (e.g. visible, water vapor, IR) are available to forecasters to analyze and diagnose the current state of the atmosphere (Silva Junior, 2010), which in turn help them to assess the quality of the numerical weather prediction (NWP) outputs in representing the current state (McGinley *et al*. 1992).

Several variational data visualization tools or systems are available nowadays but they are implemented in centres where large computational resources are available and are generally used for global analysis (Ouellette, 2013). These sophisticated technologies for visualization are essential for bridging the gap between such systems and users. For Kehrer (2011) typical visualization tasks cover visual exploration, visual analysis and presentation. In other words, visualization is concern to generate static images that can represent geostationary satellite data. Furthermore, going beyond the visualization analysis, complex data manipulation requires solutions "out-of-core" including hardware and software techniques (Nocke *et al*. 2008).

Applicative tools (e.g. ILWIS, McIDAS-V, TerraMA$^2$) allow the forecaster to combine data types into single displays. For instance, Nocke *et al*. (2008) highlights that designing intuitive and meaningful visual representations in climate context faces a variety of challenges. The first thing to consider is the heterogeneity and diversity of climate related data. The most common view of climate data uses the gridded format. Grids are used to group data and can aggregate

information just using columns and lines or adding colors. But this is not the best way to make spatial and temporal information understandable. So, using 2D-maps or 3D objects is a way to represent multivariate and region-based information.

Currently, there are a variety of important forecasting tools, or guidance information that forecasters use, different ones for different forecasting ranges, and relevance depends on the climatic regime (polar, mid-latitudes, tropics). They are largely based on two kinds of production systems: one kind is based on data from observational systems, and the other is based on NWP atmospheric simulation systems; the latter often provides its data assimilation sub-system to create objective precipitation analyses from observational data, and this is mainly for amounts (McGinley *et al*. 1992). These applications require tools that can integrate geographic services and modeling based access real-time data geo-environmental (meteorological, climatic, atmospheric, hydrological, geotechnical, socio-demographic, etc.), available on the connected server the Internet (Albers, 1995).

The aim of this paper is to implement a methodology for the ingest and display process for the MSG satellite data and products into McIDAS-V, ILWIS, TerraMA[2]. A simple set of requirements are formulated. Several examples of the ingest and display process for these data and products are also presented.

The paper is organized as follows. Section 2 defines the requirements for MSG satellite Data. Section 3 describes the MSG Satellite Data and Product Formats. Section 4 details products from the Meteorological Product Extraction Facility (MPEF). Section 5 details products from the Land Surface Analisys Satellite Application Facility (LSA SAF). Section 6 details software tools at LAPIS. Section 6 shows the results and discussion. Section 7 summarizes and concludes the paper.

## 2. Data, Products and Methods
### 2.1. Requirements for MSG Satellite Data

MSG satellite data and products are distributed to the user mainly through the EUMETCast system (EUMETSAT, 2013), provide the forecaster with a great deal of information, as shown in the EUMETSAT Product Navigator (http://navigator.eumetsat.int). These data and products can be received using simple and low cost ground reception infrastructure (Figure 1).The EUMETCast system is destined to the retransmission to users in various points on the planet, of codified data and products originating from meteorological, oceanographic, and environmental satellites, via telecommunication commercial geostationary satellites in different frequencies (Barbosa, 2013). The concept of this dissemination service is based on the standard technology of Digital Video Broadcasting (DVB) (EUMETSAT, 2005).
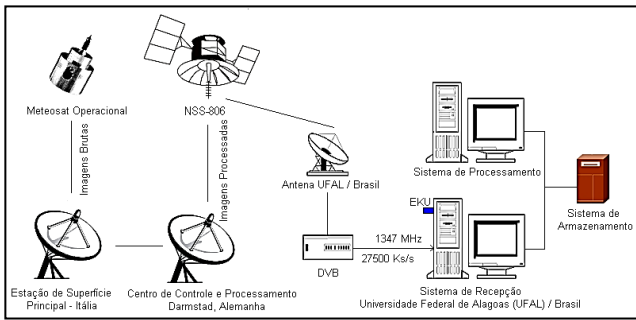
Figure 1. Overview of the broadcasting ground reception and processing system at the University of Alagoas (UFAL) in Brazil.

The antennas of the EUMETCast system users are basically divided into two types, which are destined to the Ku band reception via the Hotbird-6 satellite, and the antennas destined to the C band reception via the AtlanticBird 3 and SES-6 satellites (EUMETSAT, 2005). The C band transmits inthe cover areas of Africa and South America. While the transmission in Ku band is for Europe. The minimum diameter of the antennas is in the 2.4 m order for the South American continent (Barbosa, 2013) and 80 cm for the European continent, in Ku band. The basic antenna components are a parabolic reflector of 2.6 meters, supply with LHC polarization, and a universal LNB amplifier to amplify the signals of low-level potential, and cables for connections. To receive the signal, the antenna is pointed to NSS-806 satellite. The SES-6 is located at 40.5° west (Silva Junior, 2010).

The antenna of the user receives the PC signal and plaque (Technisat SkyStar2 TV PCI or other DVT plaque) identifies the packages (Packed ID-PID) which are transmitted in the MPEG-2 format for the EUMETSAT application, called T-System Tellicast. The PIDs are defined in the application of the DVT plaque, called Setup4PC. And the transmission of the packages is achieved via the TCP/IP protocol (Transmission Control Protocol/Internet Protocol). After the transfer, the TelliCast verifies if the eToken key (EUMETCast Key Unit-EKU) is suitable for the recuperation of the archive (EUMETSAT, 2008)

The system-configuration provides a low cost alternative to the "non-traditional meteorological" user community in Brazil applying the MSG data to a multitude of important environmental science related applications (Barbosa *et al*. 2013). The MSG capabilities and current favorable data distribution policy-license agreement of EUMETSAT, for Research and Education Institutes like the Federal University of Alagoas (UFAL), have recently opened the way for new initiatives (Barbosa, 2013)

The Laboratory for Analyzing and Processing Satellite Images (LAPIS) of the UFAL has been very active in the usage of MSG satellite data and products for over 7 years (Silva Junior, 2010). MSG satellite data was first introduced in 2007 through the direct EUMETCast readout system.

## 2.2. MSG Satellite Data and Product Formats

To carry the development of the ingest and display process for MSG satellite data and products, a simple set of requirements are formulated. The requirements for these data

and products are: i) Setting up geographic data; ii) Conversion of data and products into McIDAS-V, ILWIS, and TerraMA$^2$ tools compatible format; iii) Automatic ingest of data and products into these tool database via low cost ground reception infrastructure; iv) Ability to display these data and products in a meaningful way (readout, display, integration these data and products with other data available in EUMETCast).

The McIDAS-V, ILWIS and TerraMA$^2$ software tools produce their outputs at MSG full disk and its products over any areas defined by the user inside the chosen geographic window the MSG spatial resolution ranges approximately from 4 to 5 Km.

To carry on the ingestion of MSG satellite data into these tools it is necessary to readout of digital (raw) data. These data consist of geographical arrays of $3712 \times 3712$ pixels and a sampling distance of $3 \times 3$ km$^2$ at the sub-satellite point (except the HRV channel), i.e. the point on the Earth's surface directly below the satellite. Each pixel contains 10 bit data that represents the radiance value, expressed in $10^{-3}$ Wm$^{-2}$sr$^{-1}$[cm$^{-1}$]$^{-1}$, codified in DC form (EUMETSAT, 2013).

The processing of a full set of data of all 12 images: (i) Data acquisition stage (via EUMETCast system), (ii) Data decoding stage (calibration) and (iii) Data scientific processing stage (rectification, normalization), plus extraction of nowcasting products, is performed within a few minutes so that the data are available to the weather forecasters in near real-time. EUMETCast provide MSG images processed to Level 1.5 (EUMETSAT, 2008), obtained through the processing of satellite raw data (designated as Level 1.0 data). This processing level corresponds to image data corrected for radiometric and geometric effects, geolocated using a standard projection, finally calibrated.

EUMETSAT uses a variety of formats for storage and distribution of products. The most used types are listed below (EUMETSAT, 2013):

- Hierarchical Data Format (HDF)

Hierarchical Data Format, commonly abbreviated HDF, HDF4 or HDF5, consists of a library and multi-object file format for transferring graphical and numerical data between computers. HDF supports several different data models, including multidimensional arrays, raster images, and tables. Each defines a specific aggregate data type and provides an API to read, write and organize data and metadata. New data model scan be added by the HDF developers or users. (EUMETSAT, 2013)

- General Regularly -distributed Information in Binary Edition 2 (GRIB – 2)

GRIB (gridded binary) is the binary WMO standard format for data exchange in grid. GRIB Edition 2 is an extension of GRIB with a very high degree of flexibility and expandability. It is an efficient vehicle for transmitting large volumes of gridded data to automated over telecommunication lines with

high speed, using modern protocols centers. (EUMETSAT, 2013)

- Binary Universal Form for the Representation (BUFR)

A binary data format, maintained by the World Meteorological Organization (WMO), based on characters such as SYNOP (surface observations), TEMP (upper air soundings) and CLIMAT (monthly climatological data) codes. The BUFR tables used by EUMETSAT are established by WMO and are available on the website (http://www.wmo.int/pages/prog/www/WMO Codes.html) (EUMETSAT, 2013).

- High Rate Information Transmission (HRIT)

Low Rate Information Transmission (LRIT) CGMS standards are agreed between the satellite operators, for the dissemination of digital data via direct transmission. Quite similar to HRIT/LRIT way, the distinction between the two standards is the data rate (bandwidth) required to transmit the data content, with LRIT about 256 Kbps to 10Mbps and hrit. (EUMETSAT, 2013).

## 2.3. Products from the Meteorological Product Extraction Facility (MPEF)

The MPEF parts of the MSG Ground Segment have the function of meteorological product generation from image data from the 1.5 level provided by the Image Processing Facility (IMPF). The products are quality controlled and coded before being disseminated to the Data Acquisition and Dissemination Facility (DADF) for delivery to users. Moreover, the products generated by MPEF are transferred to the MSG Unified Meteorological Archive and Recuperation Facility (UMARF), where users can retrieve EUMETCast system online and offline (EUMETSAT, 2011). See below for reference product MPEF's.

- Atmospheric Motion Vectors (AMV)

Product generated from the images of MSG through monitoring of clouds and other atmospheric components, eg, patterns of water vapor and ozone in the synoptic scale ( ie, 100 km or larger). (EUMETSAT, 2011)

- Cloud Analysis (CLA)

The product analysis of clouds is generated based on the results of the analysis of scenes from MSG, also provided in the synoptic scale (100 km or larger). It is information about cloud cover, the cloud top temperature, cloud top pressure and cloud type phase. (EUMETSAT, 2011)

- Cloud Mask (CLM)

Product based from the results of scene analysis that provide information about cloud contamination and non- static surface types (eg, coverage of snow/ice) in a pixel area for each repeat cycle. (EUMETSAT, 2011)

- Multi-sensor Precipitation Estimate (MPE)

Providing product information precipitation rates estimated by the instantaneous pixel rain every 15 minutes. The algorithm is based on the combination data of passive microwave from the SSM/I SSMIS instruments and satellite images and

DMSP US- MSG from the data channel and IR 10.8μm. The p roduct is more suitable for convective precipitation. (EUMETSAT, 2011)

- Normalized Difference Vegetation Index (NDVI) (Barbosa, 2006)

Product that is part of the processing of the analysis of scenes based on visible and near infrared reflectance of VIS 0.6μm and 0.8μm channels, displaying information on land cover and its seasonal variation. (EUMETSAT, 2011).

## 2.4. Products from the Land Surface Analisys Satellite Application Facility (LSA SAF)

The LSA SAF (http://landsaf.meteo.pt/) is part of the SAF's network, a group of specialized development and treatment centers in the service of EUMETSAT. The main goal of the LSA SAF (LSA SAF, 2013) is to take full advantage of the remote sensing data, particularly those available by EUMETSAT, variables to measure the earth's surface, which will be used primarily for applications in meteorology. Among the products generated by the LSA SAF, See below for reference product LSA SAF's:

- Fractional Vegetation Cover (FVC)

Product that is the amount of vegetation distributed in a horizontal perspective. The product is based on three channels (VIS 0.6μm, VIS 0.8μm, NIR 1.6μm), using as input a parameter $k_0$

parametric BRDF (Bi-directional Reflectance Distribution Function) model (LSA SAF, 2013)

- Land Surface Temperature (LST)

The product are performs measurements of surface temperature in regions of clear sky through images thermal infrared (Channels IR 10.8μm and IR 12.0μm) of MSG. (LSA SAF 2013)

## 2.5. Software Tools at LAPIS

The software tools presented here is that currently used in the Laboratory for Analyzing and Processing Satellite Images (LAPIS, http://www.lapismet.com).

- McIDAS –V software

The Space Science and Engineering Center (SSEC) and the University of Wisconsin-Madison have actively developed the McIDAS since 1973. The McIDAS - V is available in http://www.ssec.wisc.edu/mcidas/software/v/ currently in active development. This system is a set of sophisticated software packages that perform a variety of functions for processing images from weather satellites and other geophysical data in two and three dimensions, observation data, numerical predictions, and other geophysical data. Among these functions, include display, analysis, interpretation, acquisition and management of data. (McIDAS, 2013).

McIDAS-V in the processing of any data type requires local or remote servers, configured by McIDAS-V Data Explorer. A local server is configured from a data folder

created on the same computer on which the program is installed, while the remote server is configured via a link directory access data over the Internet. Therefore, for the data to be inserted in a local server configuration platform, it is necessary that you know some specifications as data type and format, just so you can choose the product to be ingested. This platform is composed of three tabs (Figure 2), Data Sources (A), Field Selector (B) and Layer Controls (C), which correspond to the configuration of the servers of the data to be used, selection of what type of information is generated from the file chosen and customization of processing results, respectively. For displaying the results of processing, McIDAS-V has another interface.
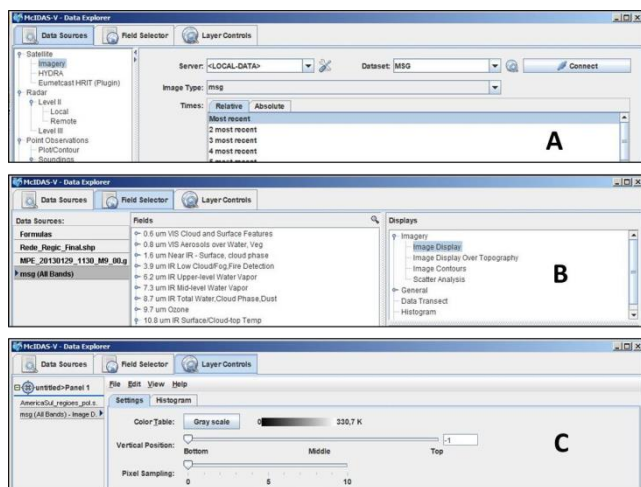


Figure 2. Processing steps of the MSG in McIDAS.

▪ ILWIS software

Integrated Land and Water Information System (ILWIS) is a tool for working with spatial data that integrates GIS and remote sensing. Was developed by ITC (Institute for Aerospace Survey and Earth Sciences), is available free on the internet in several versions

(http://52north.org/communities/ilwis/download). The ILWIS is an open source software (binaries and source code), and it is understood a complete package of image processing, spatial analysis and digital mapping. It is possible to integrate raster image processing (in matrix form) and vector.

In ILWIS was used plugin Geonetcast Toolbox for processing. It allows direct import of data EUMETCast system and processes those using ILWIS or other systems for geospatial analysis (Figure 3). To use the graphical interface, the settings can be made from an input directory, another departure and date of data to be processed.



Figure 3. Interface of the Geonetcast Toolbox.

▪ Terra View and Terra MA$^2$ softwares

For data processing, Terra View 4.0.1 (http://www.dpi.inpe.br/terraview/index.php) aplication that is associated with the Terra MA² (http://www.dpi.inpe.br/terrama2/english/index.php). Was used Terra MA² version 3.0 software and FVC product was used in ASCII grid format. In figure 4 shows a schematic overview of the functioning of Terra MA$^2$ software.
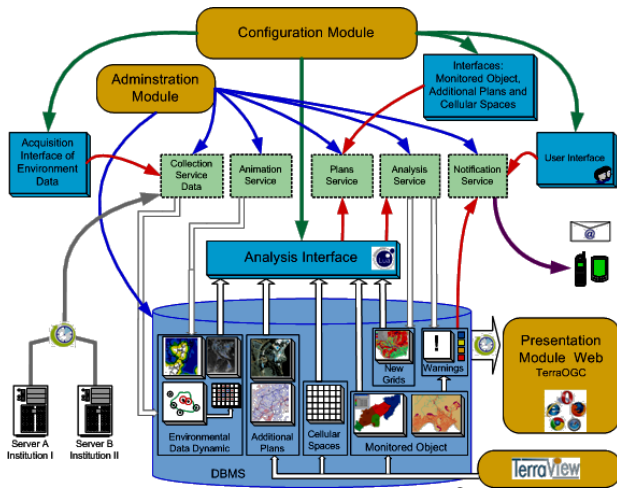
Figure 4. Diagram of the TerraMA$^2$. Source: (http://www.dpi.inpe.br/terrama2/english/arquitetura.php).

The TerraView is an application built on the library geoprocessing TerraLib that handles vector (points, lines and polygons) and raster (grids and images) data, both stored in DBMS relational or geo-relational market, including ACCESS, PostgreSQL, MySQL, Oracle, SQLServer and Firebird (TERRAVIEW, 2010). All data used for the analyzes on Terra MA² is first processed on TerraView.

## 3. Results and discussion

The ingest of MSG satellite data and products from LAPIS from direct EUMETCast readout system is accomplished using a McIDAS-V, ILWIS, and TerraMA$^2$. A few examples are shown to highlight how these data and products can be displayed on computer screen.

## 3.1. For MSG satellite data and product display

In reality McIDAS-V is able to read and display MSG data. Here McIDAS-V has

been chosen because it includes more general satellite data (MSG, GOES, etc.) formats that are standard projections so that it is quite independent of the specific satellite platform. Figure 5 shows the MSG full disk images for display on McIDAS-V in a grey scale and enhanced colours (on January 29, 2013 at 1200 UTC).
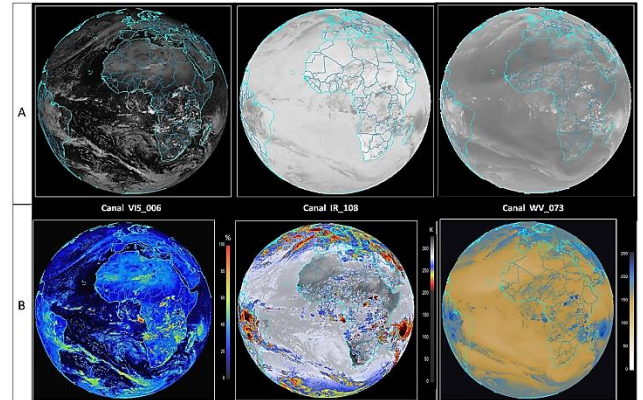


Figure 5. Ingest of MSG satellite data in the VIS, WV and IR spectral bands in a grey scale and enhanced colours into the MCIDAS-V

The interpretation of MSG satellite images can be strongly supported and facilitated when multispectral image data are presented in appropriate physical measurements of atmospheric reflectivity (VIS_006), the cloud top temperature (IR_108) and amount of water vapor in the middle levels of the atmosphere (WV_073), as shown in Figure 5.

The gridded MSG satellite data have to set into TerraMA$^2$ tool. This tool is a complex numerical system conceived to perform gridded analyses by merging together numerous data sources. Figure 6 shows MSG thermal imagery (IR_10.8) ingested into TerraMA$^2$, expressed in a gray scale image (0 to 255 levels). This image data contains 8-

bits per pixels and thus the adoption of the TerraMA$^2$ implies a data loss in terms of radiometric accuracy since MSG data has 10-bits per pixel. A special script is written that places the MSG data into input files for the TerraMA$^2$.
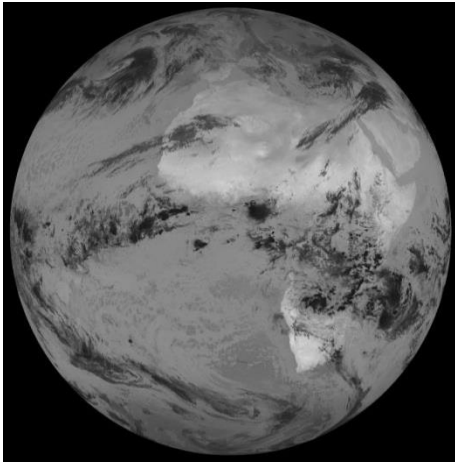


Figure 6. MSG IR_10.8 thermal imagery ingested into TerraMA$^2$.

Figure 7 shows the ingestion of MPE product (on January 29, 2013 at 1130 UTC) into McIDAS-V. This product is classified by a scale similar to the colors used by EUMETSAT (http://oiswww.eumetsat.org/IPPS/html/MSG/ PRODUCTS/MPE/America/index.htm) ranging from blue (0 mm/hr), green (5 mm/hr), yellow (15 mm/hr), orange (25 mm/hr) and red (35 mm/hr). While MPE product sub-image extraction for the McIDAS-V shows the re-projected data over South America. A vertical cross section at the latitude of the MPE maximum (that is located approximately in the top of the figure) is displayed.
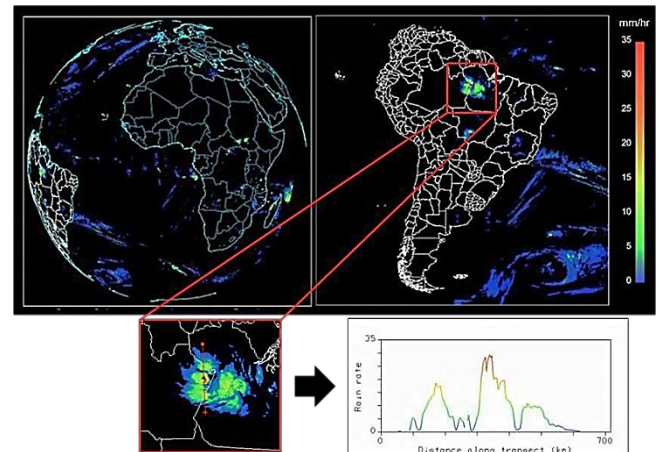


Figure 7. MPE product image ingested into McIDAS-V.

## 3.2. For meteorological analysis: clouds and rainfall

In order to verify the ability of the ILWIS analysis in reproducing the MSG full disk imagery on May 19, 2013 to 1145 UTC, the MPE, cloud mask, cloud top height and their difference maps are displayed in Figure 8. These products are used extensively during the rainy season to track precipitation over the Amazon Basin. Clouds and precipitation observations (e.g. human observer, automatic weather stations, radar and satellite systems) are however very important data to verify model precipitation forecasts and to validate its physical processes.
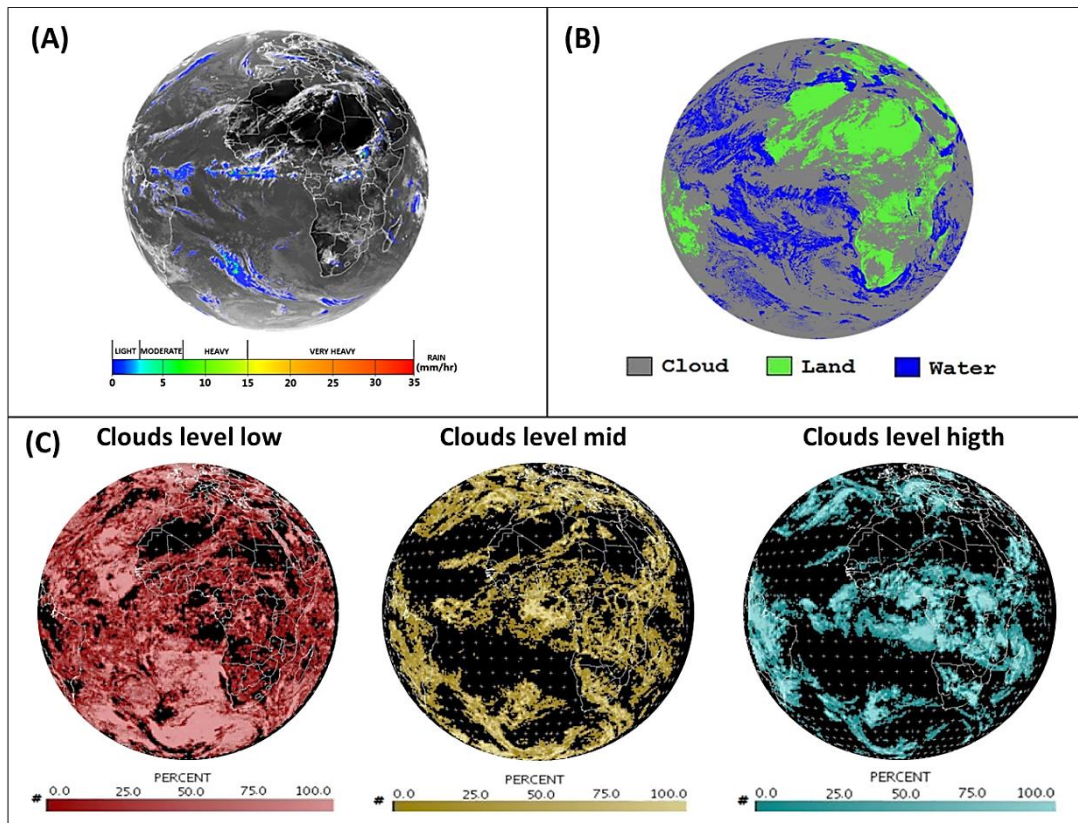
Figure 8. MPE, cloud mask and cloud top height products ingested into the ILWIS

Due to the complex nonlinear relationship between precipitation and cloud properties (e.g. temperature, texture, and morphology), it is often difficult to find the mapping between precipitation derived from satellites and that observed from the ground instruments (Stephens and Kummerow, 2007). Such mapping can be useful to understand and correct the biases from the satellite measurements of precipitation.

A preliminary comparison is performed for MPE product from EUMETSAT, precipitation observations from automatic weather stations obtained from Brazilian Met Service (INMET), GOES precipitation product from Brazilian Institute for Spatial research – CPTEC/INPE) cumulative from 1000 to 1100 UTC on September 18, 2012, when a strong convective component embedded in frontal system was observed over South Brazil.

Figure 9 shows how MPE can be compared to both the GOES precipitation estimates (hydroestimator) from CPTEC/INPE and automatic weather stations. This is a very useful way for a forecaster to evaluate the precipitation estimates in Brazil. It is apparent from this comparison that the general distribution of rainfall represented in the MPE matches what the surface observations (INMET) very well. The GOES/CPTEC/INPE (infrared) may be slightly under-predicting the precipitation in the South Brazil. It is also shown how the MPE product can be used with numerical weather model guidance.
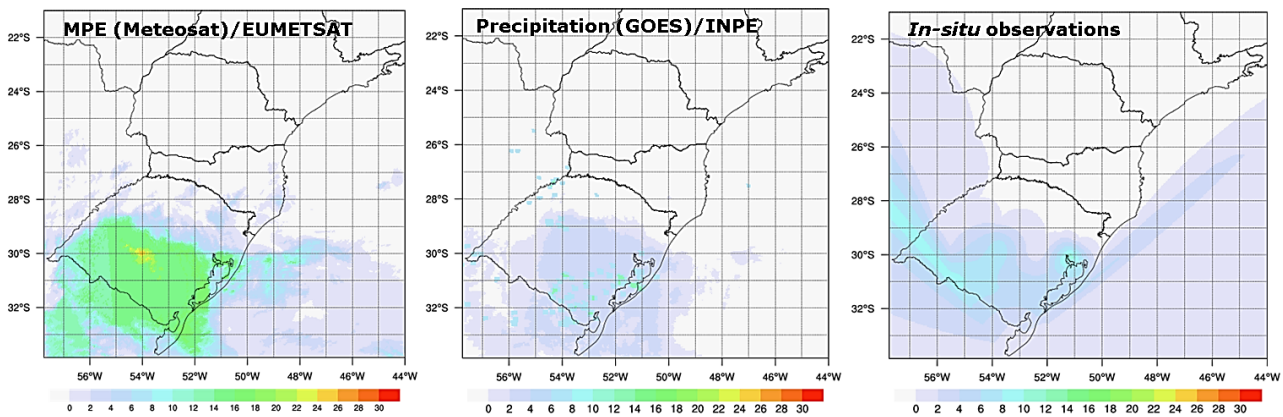
Figure 9. Examples of map cumulative precipitation from 1000 to 1100 UTC on September 18, 2012 over South Brazil estimated by MPE, GOES and automatic weather stations.

Satellite infrared measurements give marginal accuracy because of the poor relationships between cloud-top temperature and the underlying clouds and precipitation physics (Levizzani *et al*. 2002). Microwave measurements are affected by sensitivity to land surface emissitivity and by similar optical properties of cloud water and light rainfall. As a consequence, satellite precipitation estimates have many limitations vis – a – vis the direct (point) ground measurements from weather stations.

## 3.3. For land–atmosphere interactions: FVC and MPE products

The sensitivity of TerraMA[2] to the ingestion of FVC (Fraction Vegetation Cover) and MPE products is displayed. Figure 10 shows FVC and MPE products are geographically overlapped to generate a spatial pattern that allows for identifying the differences in vegetation and rainfall outputs. The FVC product is the one biophysical parameter that determines the contribution partitioning between bare soil and vegetation

for surface evapotranspiration, photosynthesis, albedo, and other fluxes crucial to land–atmosphere interactions.
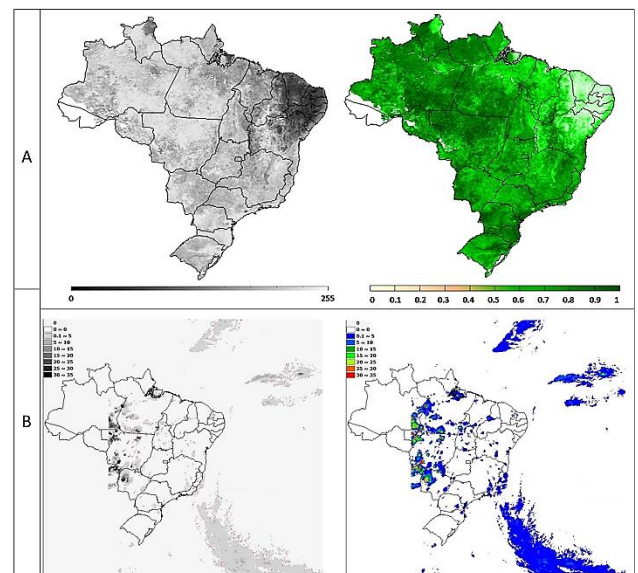


Figure 10. FVC and MPE products ingested into TerraMA[2]

Figure 11 shows the spatial variations of the re-projected FVC product over the Northeastern Brazil and its municipalities. The figure clearly indicates high spatial patterns in FVC variability. This could be due to the mixing of significant fraction of observed pixels for the "low FVC values" and "high FVC values" within the municipalities. Overall, the FVC product is able to be

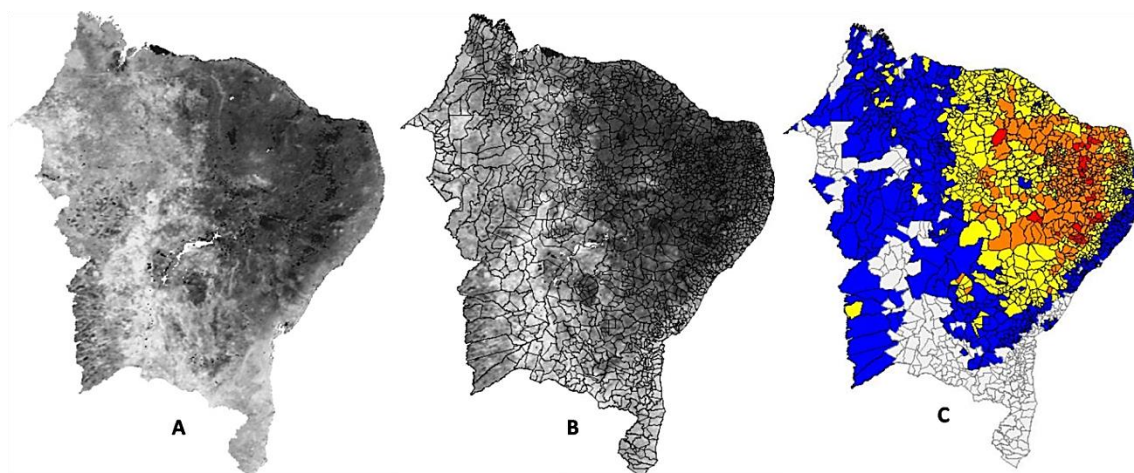ingested into TerraMA² over the municipalities analysed.



Figure 11. FVC ingested into Terra MA²

In order to verify the ability of the ILWIS analysis in reproducing the characteristics of vegetation dynamics over the Alagoas' states, FVC and NDVI products have also been examined. Figure 12 shows how the vegetation indices (FVC and NDVI products) can be combined with other data (SRTM, DEM) data that are available on ILWIS. The integration process between NDVI and FVC products occurs in two main steps. First, for each time step taken into account, Digital Elevation Model (DEM) and FVC product are geographically overlapped to generate a spatial pattern that allows for separating the topographic effect in vegetation cover outputs. Two products are used to quantify the similarities and differences, which are ingested into ILWIS tools. This integration of products has proven to be very useful to the researchers at universities.
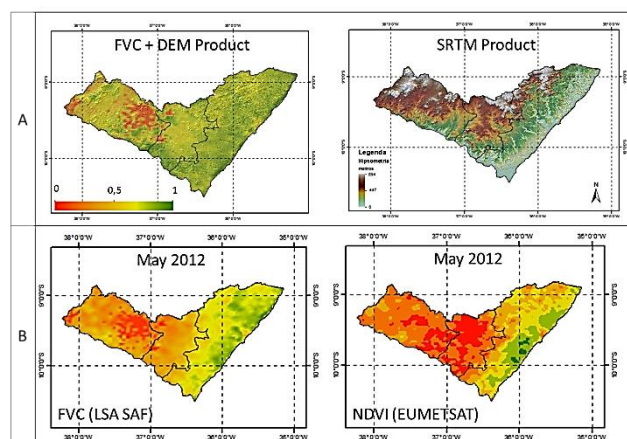


Figure 12. FVC, NDVI, DEM and SRTM products ingested into ILWIS

## 4. Summary and Conclusion

MSG-based satellite data (e.g. visible, water vapor, IR spectral bands) and products (MPE, cloud top height, FVC, NDVI) were ingested into McIDAS-V, ILWIS and TerraMA². To accomplish all of these inputs, a simple set of requirements were formulated. The requirements for these data and products were: i) Setting up geographic data; ii) Conversion of data and products into McIDAS-V, ILWIS, and TerraMA² tools compatible format; iii) Automatic ingest of data and products into these tool database via

low cost ground reception infrastructure; iv) Ability to display these data and products in a meaningful way (readout, display, integration these data and products with other data available in EUMETCast).

Therefore McIDAS-V, ILWIS and TerraMA$^2$ are very useful tools to researchers and forecasters in the input and display process for MSG satellite data and products from direct EUMETCast readout system.

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## 6. References

Albers, S., 1995. The LAPS wind analysis. Weather Forecasting. Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO 10, 342-352. [available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.56.5629&rep=rep1&type=pdf].

Barbosa, H. A. Sistema EUMETCast: Uma abordagem aplicada dos Meteosat Segunda Geração. 1ed.Maceió: EDUFAL, 2013, v. 2, 186p.

Barbosa, H. A., Huete, A., Baethgen. 2006. A 20-year study of NDVI variability over the Northeast region of Brazil, Journal of Arid Environments, 67, 288-307

Barbosa, H. A., Silva Junior, I. W, Macedo Silva, L. R. 2011. Experiência da UFAL em recepção, decodificação e processamento das imagens do satélite Meteosat segunda geração (MSG). Mudanças Climáticas. Editora UFPE. Edição 1. Recife.

Barbosa, H. A.; Kumar, T. L. 2012. Strengthening Regional Capacities for Providing Remote Sensing Decision Support in Drylands in the Context of Climate Variability & Change. In: Silvern, S.; Young; S. (Org.). International Perspectives on Global Environmental Change. 2ed.Croatia: INTech, v. 1, p. 3-312.

Barbosa, H. A.; Tote, C. ; Lakshmi Kumar, T. V.; Bamutaze, Y. 2013. Harnessing Earth Observation and Satellite Information for Monitoring Desertification, Drought and Agricultural Activities in Developing Countries. In: Silvern, S.; Young; S. (Org.). Environmental Change and Sustainability. 3ed. Croatia: INTECH, v. 1, p. 3-301.

EUMETSAT, 2008. A simple conversion from effective radiance back to spectral radiance for MSG images, document n. 1053. [available from: http://www.eumetsat.int/idcplg?IdcService=GET_FILE&dDocName=pdf_msg_conv_effrad2specrad&RevisionSelectionMethod=LatestReleased].

EUMETSAT. 2013. About EUMETSAT. Disponível em: http://www.eumetsat.int/Home/Main/AboutEU METSAT/index.htm?l=en. Data de acesso: 03/02/2013a

EUMETSAT. 2013. EUMETSAT utilises a variety of formats for product storage and distribution. The most commonly used types are listed below. Disponível em: http://www.eumetsat.int/website/home/Data/Pr oducts/Formats/index.html. Data de acesso: 06/07/2013c.

EUMETSAT. 2013. The atmospheric information available from our satellites has wider benefits than its contribution to weather forecasting. Disponível em: http://www.eumetsat.int/website/home/Data/Pr oducts/Atmosphere/index.html. Data de acesso: 06/07/2013d.

EUMETSAT. MSG 2011. Meteorological Products Extraction Facility: Algorithm Specification Document. Disponível em: http://www.eumetsat.int/Home/Main/DataP rod ucts/Atmosphere/index.htm. Data de acesso: 14/03/2013. Germany.

EUMETSAT. MSG: 2005. Meteosat Second Generation, in orbit – in use. Germany. p1-37.

ILWIS. 2013. ILWIS, the free user-friendly raster and vector GIS. Data de acesso: 02/02/2013 [available from: http://www.ilwis.org/]

Instituto Nacional de Pesquisas Espaciais – INPE. Plataforma de Monitoramento, Análise e Alerta – TerraMA2. 2014. Disponível em: <http://www.dpi.inpe.br/terrama2/>. Acesso em: 27 março 2014.

Kehrer, J. 2011. Interactive visual analysis of multi-faceted scientific data (Doctoral dissertation, PhD dissertation, Dept. of Informatics, Univ. of Bergen, Norway).

LSA SAF. 2013. Product User Manual: Vegetation parameters. Portugal, 2008. Disponível em: http://landsaf.meteo.pt/products/prods.jsp. Data de acesso: 13/03/2013.

McGinley, J. A., Albers, S. C., Stamus, P. A., 1992. Local data assimilation and analysis for nowcasting. Adv. Space Res. 12, 179-188.

Nocke, T., Sterzel, T., Böttinger, M., & Wrobel, M. 2008. Visualization of climate and climate change data: An overview. Digital earth summit on geoinformatics, 226-232.

Ouellette, J. 2013. The Mathematical Shape of Things to Come - Scientific data sets are becoming more dynamic, requiring new mathematical techniques on par with the invention of calculus In: Quanta Magazine, October 4.

Silva Junior, I. W. 2010. Desenvolvimento de aplicações operacionais para o monitoramento meteorológico, ambiental e oceanográfico utilizando dados do sistema EUMETCast. Dissertação (Mestrado em Meteorologia), UFAL, Maceió.

TERRAVIEW 4.1.0. 2013. Projeto TerraView. São José dos Campos, SP: INPE, 2010. Disponível em: www.dpi.inpe.br/terraview. Acesso em: 24/02/2013.

UNEP. 2008. Climate change strategy, United Nations Environment Programme.

Wolf L and Williams M. 2008. GEONETCast - Delivering environmental data to users worldwide (September 2007). IEEE Systems Journal, vol. 2, No. 3.