NASA IMAGESEER: NASA IMAGEs for Science, Education, Experimentation and Research

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ABSTRACT

A number of web-accessible databases, including medical, military or other image data, offer universities and other users the ability to teach or research new Image Processing techniques on relevant and well-documented data. However, NASA images have traditionally been difficult for researchers to find, are often only available in hard-to-use formats, and do not always provide sufficient context and background for a non-NASA Scientist user to understand their content. The new IMAGESEER (IMAGEs for Science, Education, Experimentation and Research) database seeks to address these issues. Through a graphically-rich web site for browsing and downloading all of the selected datasets, benchmarks, and tutorials, IMAGESEER provides a widely accessible database of NASA-centric, easy to read, image data for teaching or validating new Image Processing algorithms. As such, IMAGESEER fosters collaboration between NASA and research organizations while simultaneously encouraging development of new and enhanced Image Processing algorithms. The first prototype includes a representative sampling of NASA multispectral and hyperspectral images from several Earth Science instruments, along with a few small tutorials. Image processing techniques are currently represented with cloud detection, image registration, and map cover/classification. For each technique, corresponding data are selected from four different geographic regions, i.e., mountains, urban, water coastal, and agriculture areas. Satellite images have been collected from several instruments - Landsat-5 and -7 Thematic Mappers, Earth Observing -1 (EO-1) Advanced Land Imager (ALI) and Hyperion, and the Moderate Resolution Imaging Spectroradiometer (MODIS). After geo-registration, these images are available in simple common formats such as GeoTIFF and raw formats, along with associated benchmark data.

Keywords: image processing, benchmark datasets, validation, NASA-centric data, Earth Science

1. INTRODUCTION

As the amount of NASA image data tremendously increases in the areas of Earth, Planetary and Exploration Sciences, the need for fast (and often real-time), automatic or semi-automatic and accurate image processing methods increases as well. State-of-the-art image processing technologies have been developed and applied for many years to the military, medical and commercial domains, but the application of these methods to NASA image processing challenges lags behind these other domains. Often, the barrier to test newly developed algorithms on NASA-generated data is the difficulty in easily obtaining image data in a format that is manageable by the university computer science community, as well as knowledge of the application domain and of the desired scientific results. Additionally, often the NASA scientific community relies on tools offered as part as off-the-shelf commercial systems, and no specific additional research and development needs are being sought. As a consequence, the application of image processing to NASA data has often been restricted to older, well-tested off-the-shelf methods that are not always optimal for NASA applications.

An example of this last issue is illustrated by the problem of geo-locating remotely sensed image data [1]. The geo-location problem can be summarized in the following way: when an image is acquired by a satellite instrument it is relatively easy to align the image with a specific geographic location in a general sense (e.g., "this is an image of the Chesapeake Bay"). However, meaningful scientific results require very accurate determination of the images geographic location (or geo-location). A good geo-location, or registration, algorithm has to take into account many factors such as satellite orbits, sensor characteristics, atmospheric and cloud interactions, multi-temporal and multi-sensor effects, etc. After a systematic geometric correction based on the sensor specific navigation model is performed, a more accurate geo-location can be obtained by using image registration based on image features. Until very recently, most remotely sensed pairs of images were registered in systems such as ENVI, using semi-automatic methods, with a very labor-intensive first step of visually locating corresponding features in the pair of images. It is only in the last few years that many projects (e.g., Landsat, MODIS, SeaWIFS, MISR) have developed image registration methods to perform this step entirely automatically. But these methods are adopted on a case-by-case basis and the tools currently included in off-the-shelf packages do not generally satisfy all Science projects requirements. However, such registration methods have existed in other domains for many years, for example in the medical domain where benchmark data including fiducial points have been available to validate any new image registration methods [2].

Consequently, the objective of IMAGESEER is to build a database of image test data (or benchmark or validation data), with each dataset being stored in at least 2 different, easily readable, formats by the university community. Along with the data, the following information is provided:

- Basic knowledge of the application domains
- "Truth data" results (e.g., classification map for image classification algorithms, transformation parameters for Image registration algorithms, features locations for image analysis algorithms, etc.)
- Specific problems to be solved, as defined by domain scientists.

The value of IMAGESEER is in providing:

- Illustrative NASA-centric examples for Image Processing and Computer Vision (IP&CV) university courses
- Benchmark NASA Science data for new IP&CV research algorithms
- Potential topics for Masters and PhD research of interest to NASA.

The three main goals of IMAGESEER are to foster collaboration between NASA centers and universities, to train and attract students in NASA-related work and to leverage a wide IP&CV expertise that has already been developed for military, medical and commercial applications, and that can be adapted to NASA challenges.

This paper will first provide a brief survey of other image databases available to the Image Processing community and will describe what are the specific needs leading to a NASA-centric image database. Then, the technical description of IMAGESEER, its contents and its web-based user interface will be given with a few illustrative screen shots. Finally, future potential extensions of this preliminary prototype will be described.

2. BACKGROUND

2.1 Need for a NASA-centric image database

Various benchmark image datasets are available for teaching image processing and for validating new algorithms [2-5]. Figure 1 shows examples listed on the website "ImageProcessingPlace.com" [3]. Another compilation of such databases is also provided on the Carnegie Mellon University website, "Computer Vision Test Images" [4]. These databases contain: "standard" test images that have been traditionally utilized in the Image Processing field; images from various domains (medical, military, weather, faces, fingerprints, etc); and test images that can be used for various image processing techniques such as motion detection, segmentation, shape recognition, image processing or scene understanding [4]. Despite these various resources, very few databases include NASA-related data, and even less associated NASA-centric applications, although NASA images present specific challenges usually not illustrated in other types of imagery. Some of these challenges are the following:

- *The variety in the types of sensor data and the conditions of data acquisition*. A technique that appears to work accurately on satellite imagery acquired at a given time over some given location may not perform as well on data from the same sensor at other times or over another location. For example, in Earth Science, varying atmospheric conditions (e.g., clouds, sun angle, etc) can distort sensor readings taken of the same location at different times
- *The size of the data*. For example, a typical Landsat scene is of size 7000x7000 pixels on average, containing 7 bands whose wavelength varies from the visible to the thermal infrared range. Handling such amounts of data in real-time must take into account computational requirements such as speed

and memory. As a consequence, the implementation of such methods on parallel, distributed or even on-board computers must be considered

- *The lack of a known image model*. Similarly to fiducial points, a very rough sketch of a city, containing a river or a network of roads, can be utilized as a global model for Earth Science scenes; or a geological map can be utilized for planetary data. However, this usually lacks either the amount of detail and/or the degree of invariance to acquisition conditions (e.g., atmospheric and seasonal variations) that would be needed for optimal and reliable image processing
- *The lack of well-distributed "fiducial points" or natural "truth data" resulting in the difficulty to validate image processing methods in the NASA domain*. For example, for geo-registration of Earth Science data, it is possible to use well-known landmarks such as the Washington Monument or the Eiffel Tower as fiducial points, but such landmarks are very rare, and are not evenly distributed around the globe. The key factor in any accuracy assessment of satellite data is linked to the ability to gather ground reference data independently of the satellite data themselves. Additionally, depending on the time between the on-site ground reference gathering and the imaging of the area, the validity of the ground reference data may be lessened due to anthropomorphic or natural influences. Another approach is to compare the digital image with other sources of ground reference data, such as other instruments data or appropriate reference maps, provided that the features of interest are detectable using these sources. The degree of correspondence between the ground reference data and the measurement derived from the sensor data can then be compared for accuracy assessment.

2.2 Brief Survey of image databases containing NASA data

Among all the databases cited in the previous section, few contain Earth remote sensing data and space data [6-11]. These can be classified into two types:

(1) Large repositories such as the NASA Distributed Active Archive Centers (the DAAC's), the University of Maryland Global Land Cover Facility (GLCF), the Planetary Data System (PDS) and the USGS Earth Resources Observation and Science (EROS) Center [6-9]. Those data collections, aimed at Scientists working in Earth or Space Science, usually require a great deal of background knowledge in order to search, read, and interpret the data. First, image processing students or researchers are not necessarily familiar with the different types of space sensors used to capture the data, do not have the tools necessary to read some domain specific formats (such as the Hierarchical Data Format (HDF) or the Flexible Image Transport System (FITS) format), and can also be overwhelmed by very large scenes and large numbers of wavelengths. Then, even if these obstacles are overcome, another issue is to know how to interpret the data and how to use them for image processing algorithms teaching or benchmarking.

(2) Smaller image data collections such as the NASA Image Exchange (NIX, [10]) or the Jet Propulsion Laboratory (JPL) Photojournal [11] focusing on some well-selected and illustrative images from various NASA domains. NIX, sponsored by NASA Scientific and Technical Information (STI) Program, illustrates all aspects of NASA work, from Aeronautics to Wind Tunnels, while Photojournal only concentrates on planetary images. These image databases, using formats accessible to a wider audience (such as tiff or jpeg) are closer in spirit to the proposed focus of IMAGESEER. The number of images included in those databases is also similar to the intent of the IMAGESEER database. On the other hand, these data collections represent "image galleries" used for public outreach, or for illustrative purposes, and they cannot be used as benchmark datasets; no validation images are systematically provided for each dataset and on the same website, and no systematic education material is included, and of course, those databases do not specifically target the image processing community.

In comparison to these other web portals, the innovation of IMAGESEER is not only to assemble a collection of test data but also to provide accompanying validation and education data that explain the needs of the corresponding NASA Science application and that give some truth data needed to assess the quality of new algorithms.

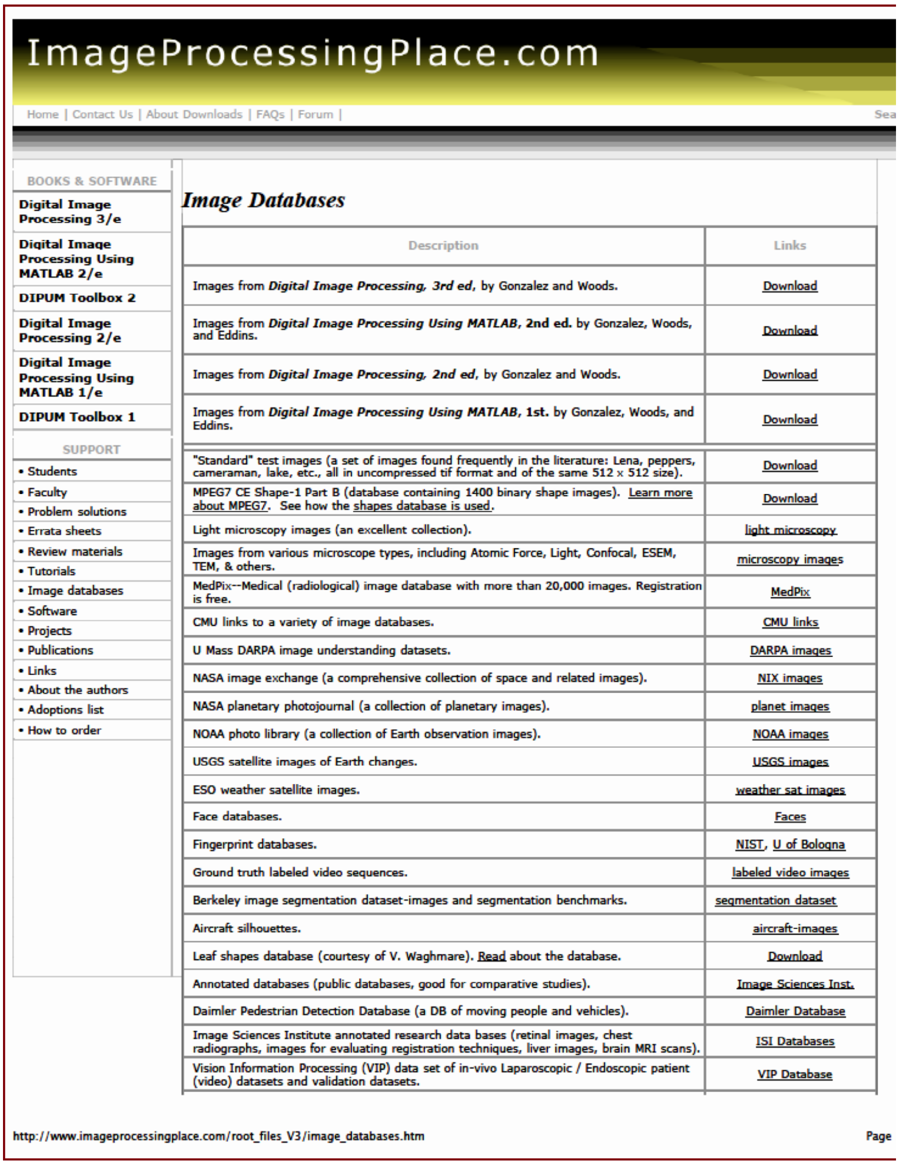

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Image Databases

Description	Links
Images from ***Digital Image Processing, 3rd ed***, by Gonzalez and Woods.	Download
Images from ***Digital Image Processing Using MATLAB*, 2nd ed.** by Gonzalez, Woods, and Eddins.	Download
Images from ***Digital Image Processing, 2nd ed***, by Gonzalez and Woods.	Download
Images from ***Digital Image Processing Using MATLAB*, 1st.** by Gonzalez, Woods, and Eddins.	Download
"Standard" test images (a set of images found frequently in the literature: Lena, peppers, cameraman, lake, etc., all in uncompressed tif format and of the same 512 x 512 size).	Download
MPEG7 CE Shape-1 Part B (database containing 1400 binary shape images). Learn more about MPEG7. See how the shapes database is used.	Download
Light microscopy images (an excellent collection).	light microscopy
Images from various microscope types, including Atomic Force, Light, Confocal, ESEM, TEM, & others.	microscopy images
MedPix--Medical (radiological) image database with more than 20,000 images. Registration is free.	MedPix
CMU links to a variety of image databases.	CMU links
U Mass DARPA image understanding datasets.	DARPA images
NASA image exchange (a comprehensive collection of space and related images).	NIX images
NASA planetary photojournal (a collection of planetary images).	planet images
NOAA photo library (a collection of Earth observation images).	NOAA images
USGS satellite images of Earth changes.	USGS images
ESO weather satellite images.	weather sat images
Face databases.	Faces
Fingerprint databases.	NIST, U of Bologna
Ground truth labeled video sequences.	labeled video images
Berkeley image segmentation dataset-images and segmentation benchmarks.	segmentation dataset
Aircraft silhouettes.	aircraft-images
Leaf shapes database (courtesy of V. Waghmare). Read about the database.	Download
Annotated databases (public databases, good for comparative studies).	Image Sciences Inst.
Daimler Pedestrian Detection Database (a DB of moving people and vehicles).	Daimler Database
Image Sciences Institute annotated research data bases (retinal images, chest radiographs, images for evaluating registration techniques, liver images, brain MRI scans).	ISI Databases
Vision Information Processing (VIP) data set of in-vivo Laparoscopic / Endoscopic patient (video) datasets and validation datasets.	VIP Database

http://www.imageprocessingplace.com/root_files_V3/image_databases.htm Page

Figure 1. List of Image Databases Available at ImageProcessingPlace.com

3. TECHNICAL DESCRIPTION

3.1 Overall description

The IMAGESEER concept was developed under the NASA Goddard Space Flight Center's Internal Research and Development (IRAD) program and was designed in collaboration with both the NASA Science and the University communities. A first prototype is available at http://imageseer.nasa.gov. As shown in our first prototype, we are using a graphically-rich web site for easily browsing and downloading all of the selected datasets, benchmarks, and tutorials. Using a paradigm common on commercial websites, users can restrict their searches by selectively filtering by data source (project, mission, and instrument), region of interest, desired image processing technique, and time period. By deliberately focusing on only a subset of NASA data, continuously emphasizing ease-of-use, providing common file formats, and supplying the "answers" as well as the questions to NASA image processing challenges, IMAGESEER provides an easily navigable and usable web site for non-NASA researchers. On the back-end, automated python scripts convert and pre-process the NASA data (e.g. for subsetting, registration and cloud detection), generate thumbnails and benchmarks, and populate the IMAGESEER database. IMAGESEER is a heavily data-driven website, where the database tracks all relevant information about the images including missions, bands, locations, capture time, and truth data. The IMAGESEER database is built using MySQL database with NNN tables. Four pieces of information are automatically compiled on the image repository and imported into the database: scenes, scene files, truth data, and the interconnections between the other first three items and themselves; mission information is also included. The web site was developed using Hyper Text PreProcessor (PHP).

Since IMAGESEER's primary goal is to help researchers and students experiment and learn NASA image processing techniques using real NASA data, the main emphasis has been placed on the users being able to easily find meaningful data for a particular technique, neither having to worry about learning esoteric file formats nor struggling with low-level unexpected issues (e.g., is the data correctly geo-registered to the correct latitude/longitude), and easily finding the best "answers" currently used by NASA scientists for a given challenge.

As such, IMAGESEER's development has focused on two main problems:

- Obtaining, correcting, and normalizing representative NASA data along with possibly generating associated truth data
- Creating a web site to easily find, display and download the data

3.2 IMAGESEER content description

The first prototype of IMAGESEER currently focuses on the Earth Science domain, though there are definite plans to extend IMAGESEER to other NASA domains. Working with project scientists and engineers, IMAGESEER identified Earth Science applications of interest and their corresponding image processing techniques with accompanying data, data types and database requirements.

More specifically, we performed a preliminary identification of:

- *The types of image processing problems* to use for training/teaching, namely, we identified 4 techniques: (1) Map Cover/Classification, (2) Cloud Detection, (3) Image Registration, and (4) Gap Filling/In-painting
- *The regions of interest.* We identified 4 regions of interest corresponding to different geographic features, Mountainous area/Colorado, Urban area/Los Angeles, Water-Coastal area/Chesapeake, and Agriculture area/Quincy (Illinois)
- *The instruments of interest*: Landsat-5/Thematic Mapper (TM), Landsat-7/Enhanced Thematic Mapper (ETM+), Earth Observing-1/Advanced Land Imager (ALI) and Hyperion, MODIS and SeaWIFS
- *The datasets sizes*: preview (thumbnail) images, 1Kx1K and almost full scenes
- *The datasets formats*: TIFF and Raw data
- *The security and privilege related issues* (e.g., related to courses or exercises proposed by the teachers vs. general access by professors, students and researchers).

Following these requirements analysis, the database was designed and implemented. The database mainly tracks three types of information: users, science data and image processing techniques.

- Data was gathered and pre-processed for four of the instruments of interest; Landsat-Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+), EO-1/Advanced Land Imager (ALI) and EO1/Hyperion. For all datasets, truth data were identified and all data was ingested into the database. In particular, along with the original data, we also acquired their associated classification maps provided by two NLCD (National Land Cover Data) maps gathered in 1992 and 2001 by the Multi-Resolution Land Characteristics Consortium (MRLC) [12]
- The user web-based interface was designed and implemented. It was recently tested for 508 compliance and IT security requirements
- The first Imagepedia articles were written on topics such as "Introduction to Remote Sensing," "Introduction to Image Processing," "Image Registration," and "Cloud Detection". Additionally, the data provenance and the process used to generate the images included in the database are also included. Therefore, if users need the same type of data at another location, they have the necessary instructions to duplicate this process

- Beta-testing is now starting so we expect a revised version of the prototype to be released in the upcoming year.

3.3 NASA data simplified

As mentioned previously, a primary goal of IMAGESEER is to provide NASA data in a familiar, easy to use format for image processing and computer scientists. This means to preprocess the NASA data to remove remote sensing artifacts and provide the data in common file formats.

Earth Science data (or scenes) are usually available as various products categorized according to the Earth Observing System (EOS) data products levels characterization [13]. The EOS data levels are defined in the following fashion:

  - Level 0 data are reconstructed unprocessed instrument and payload data at full resolution, with all communications artifacts removed

- Level 1A data are reconstructed, time-reference raw data, with ancillary information including radiometric and geometric coefficients
- Level 1B data are corrected Level 1A data (in sensor units)
- Level 2 data are derived geophysical products from Level 1 data, at the same resolution and location, e.g., atmospheric temperature profiles, gas concentrations, winds variables, etc
- Level 3 data correspond to the same geophysical information as Level 2, but mapped onto a uniform space-time grid
- Level 4 data are model output or results from prior analysis of lower-level data.

So in Levels 0 to 1B data (as defined above), pre-processing is utilized to correct for a certain number of issues that become apparent during acquisition such as geometric anomalies, terrain variation, atmospheric interactions, and various lighting conditions. This includes correcting for the detector's radiometric sensitivity, spatial adjustments, geometric adjustments, atmospheric correction, and correction for terrain effects, etc. Some other more refined product definitions are also used for specific satellites, e.g. for Landsat [14]:

  - Level 1G: Systematic corrected single scene
  - Level 1T: Terrain corrected single scene
  - Level L1Gt: Systematic terrain corrected single scene

And for EO1 [15]:

  - Level L1Gs: Radiomatrically corrected and resampled for geometric correction and registered to a geographic map projection
  - Level L1Gst: Radiomatrically corrected and resampled for geometric correction and registered to a geographic map projection. The data image is ortho-corrected using digital elevation models (DEM) to correct parallax error due to local topographic relief.

The original scenes currently included in the IMAGESEER database have been acquired from 4 different instruments, at a Level 1T (for LandSat) and 1GST (for EO-1) data:

    - Landsat-5/Thematic Mapper (TM), multispectral instrument with 7 bands
    - Landsat-7/ Enhanced Thematic Mapper (ETM), multispectral instrument with 8 bands
    - EO-1/Advanced Land Imager (ALI), multispectral instrument with 7 bands
    - EO-1/Hyperion hyperspectral sensor, hyperspectral instrument with 220 bands.

All original Landsat and EO-1 data were downloaded from one of the two following USGS websites, USGS Global Visualization Viewer (GloVis) (http://glovis.usgs.gov) and are in Geographic Tagged Image-File Format (GeoTIFF). To represent different levels of difficulty from an image processing point of view, the image features represent 4 different geographic locations: mountainous features in Colorado, urban features in the Los Angeles area, water-coastal features in the Chesapeake Bay, and agricultural features in Quincy (Illinois).

NLCD classification maps are available for 1992, 2001, and 2006. Since 2006 were not available when ground truth maps were being collected for IMAGESEER, only 1992 and 2001 were used. Image data were chosen around those dates, within a 5-year timeframe of these 2 dates, from 1990 to 1994 and from 1999 to 2003, respectively. The 1992 maps are used as classification truth data for scenes from 1990 to 1994 and the 2001 maps are used as classification truth data for scenes from 1999 to 2003. This assumes that changes in land cover were minimal within a 2-year timeframe around the land cover acquisition time.

Summary of IMAGEER Collection:													
Date of compilation: 2011-01-27 (Number													
Scene Collection:		**Totals**	**sub-totals**	**1990**	**1991**	**1992**	**1993**	**1994**	**1999**	**2000**	**2001**	**2002**	**2003**
LandSat 7		302											
	Chesapeake Bay (015033)		80	0	0	0	0	0	10	22	20	20	8
	Agriculture (025032)		66	0	0	0	0	0	12	14	16	18	6
	Mountains (035033)		86	0	0	0	0	0	16	22	18	22	8
	Urban (041036)		70	0	0	0	0	0	10	20	14	20	6
LandSat 4-5		741											
	Chesapeake Bay (015033)		183	15	24	10	26	24	20	20	12	14	18
	Agriculture (025032)		164	14	20	14	10	20	14	16	20	18	18
	Mountains (035033)		210	16	16	22	24	24	24	24	24	18	18
	Urban (041036)		184	16	18	22	20	12	18	18	22	16	22
EO-1 ALI		30											
	Chesapeake Bay (015033)		22	0	0	0	0	0	0	0	3	6	13
	Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
	Mountains (035033)		2	0	0	0	0	0	0	0	0	1	1
	Urban (041036)		6	0	0	0	0	0	0	0	3	0	3
EO-1 Hyperion		17											
	Chesapeake Bay (015033)		6	0	0	0	0	0	0	0	4	2	0
	Agriculture (025032)		1	0	0	0	0	0	0	0	1	0	0
	Mountains (035033)		2	0	0	0	0	0	0	0	0	1	1
	Urban (041036)		8	0	0	0	0	0	0	0	7	0	1
TOTAL Scene Collection:		1090											
Ground Truth Images:		**Totals**	**sub-totals**	**1990**	**1991**	**1992**	**1993**	**1994**	**1999**	**2000**	**2001**	**2002**	**2003**
NLCD													
	Chesapeake Bay (015033)		4	0	0	2	0	0	0	0	2	0	0
	Agriculture (025032)		4	0	0	2	0	0	0	0	2	0	0
	Mountains (035033)		4	0	0	2	0	0	0	0	2	0	0
	Urban (041036)		4	0	0	2	0	0	0	0	2	0	0
TOTAL NLCD		16											
Cloud Masks		**Totals**	**sub-totals**	**1990**	**1991**	**1992**	**1993**	**1994**	**1999**	**2000**	**2001**	**2002**	**2003**
LandSat 7		222											
	Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
	Agriculture (025032)		66	0	0	0	0	0	12	14	16	18	6
	Mountains (035033)		86	0	0	0	0	0	16	22	18	22	8
	Urban (041036)		70	0	0	0	0	0	10	20	14	20	6
LandSat 4-5		548											
	Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
	Agriculture (025032)		154	14	10	14	10	20	14	16	20	18	18
	Mountains (035033)		210	16	16	22	24	24	24	24	24	18	18
	Urban (041036)		184	16	18	22	20	12	18	18	22	16	22
EO-1 ALI		0											
	Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
	Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
	Mountains (035033)		0	0	0	0	0	0	0	0	0	0	0
	Urban (041036)		0	0	0	0	0	0	0	0	0	0	0
EO-1 Hyperion		0											
	Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
	Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
	Mountains (035033)		0	0	0	0	0	0	0	0	0	0	0
	Urban (041036)		0	0	0	0	0	0	0	0	0	0	0
TOTAL Cloud Masks		770											
GeoLocated:		Totals	sub-totals	1990	1991	1992	1993	1994	1999	2000	2001	2002	2003
LandSat 7		0											
	Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
	Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
	Mountains (035033)		0	0	0	0	0	0	0	0	0	0	0
	Urban (041036)		0	0	0	0	0	0	0	0	0	0	0
LandSat 4-5		0											
	Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
	Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
	Mountains (035033)		0	0	0	0	0	0	0	0	0	0	0
	Urban (041036)		0	0	0	0	0	0	0	0	0	0	0
EO-1 ALI		30											
	Chesapeake Bay (015033)		22	0	0	0	0	0	0	0	3	6	13
	Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
	Mountains (035033)		2	0	0	0	0	0	0	0	0	1	1
	Urban (041036)		6	0	0	0	0	0	0	0	3	0	3
EO-1 Hyperion		17											
	Chesapeake Bay (015033)		6	0	0	0	0	0	0	0	4	2	0
	Agriculture (025032)		1	0	0	0	0	0	0	0	1	0	0
	Mountains (035033)		2	0	0	0	0	0	0	0	0	1	1
	Urban (041036)		8	0	0	0	0	0	0	0	7	0	1
TOTAL GeoLocated:		47											

Figure 2. List of all current IMAGESEER data holdings

A total of 8 NLCD maps was collected for the 4 locations and the 2 different timeframes and will serve as reference for all other data. The NLCD maps were then re-projected from Albers Conic Equal Area projection, NAD 83 to match Landsat and EO-1 projections, Universal Transverse Mercator (UTM), WGS84. Each of the eight NLCD maps is defined by its 4 corners, given in a (lat, long) coordinate system. The instrument original scenes are acquired by searching for the rows/paths containing these coordinates, and are then processed with the following steps:

a. For each geographic area, the original scenes are geo-registered to the corresponding (spatially and temporally) NLCD map
b. From the geo-registered scenes, the portion of the scene defined by the 4 (lat, long) corners of the corresponding NLCD map is extracted. Therefore, all scenes from a given geographic area correspond to the exact same (lat, long) coordinates on the ground
c. The geo-registered scenes are processed with a cloud detection algorithm, appropriate for the instrument that acquired the scene
d. The original scenes, geo-registered scenes, extracted scenes, and cloud masks are then converted to 2 common formats, GeoTIFF and raw
e. Finally, smaller size, 1024 x 1024, scenes are extracted from the center of the geo-registered scenes.

In summary, for each scene of interest, IMAGESEER provides:

- 3 dataset sizes: preview (thumbnail) images, full scenes (around 7000X7000 pixels in all instrument bands) and a smaller sub-scene of size 1024x1024 for easy manipulation
- 2 dataset formats: Raw data, and GeoTIFF formats

Each scene can be downloaded as a zip file containing all bands or just one band at a time. Figure 2 shows a summary of all current IMAGESEER data holdings.

3.4 Truth Data

One of the particularities of IMAGESEER is to provide truth data or "validation data" for each image processing technique. Currently, most data are provided with validation data for 3 different image processing techniques, image classification, image geo-registration and cloud detection. Figure 3 shows the example of a Landsat-7 scene (Figure 3(a)) with its corresponding NLCD classification (Figure 3(c)) following the NLCD class categorization shown in Figure 3(b).

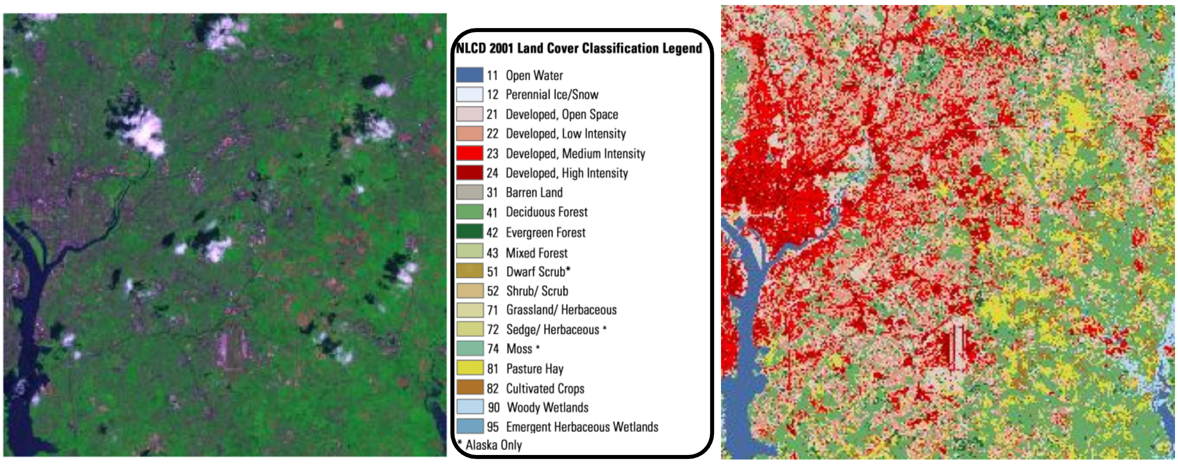

Figure 3. (a) Example of a Landsat-7 Scene; (b) NLCD Land Cover Classification Legend; (c) NLCD Classification of Figure 3(a) According to Land Cover Classes described in Figure 3(b)

Associated with this map, a graphical breakdown of the distribution of the different classes is also provided to the users: see Figure 4. Similarly, Figure 5 shows the cloud mask obtained when processing Figure 3(a) with the Automated Cloud Cover Assessment (ACCA, [16]) algorithm.

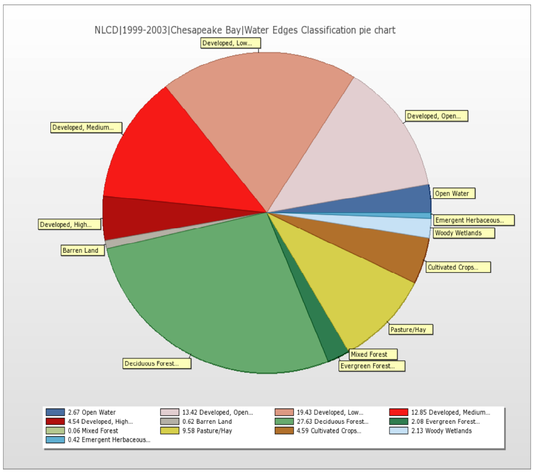

Figure 4. Image Classification Percentages for Sample scene
Scene Illustrated in Figure 2(a)

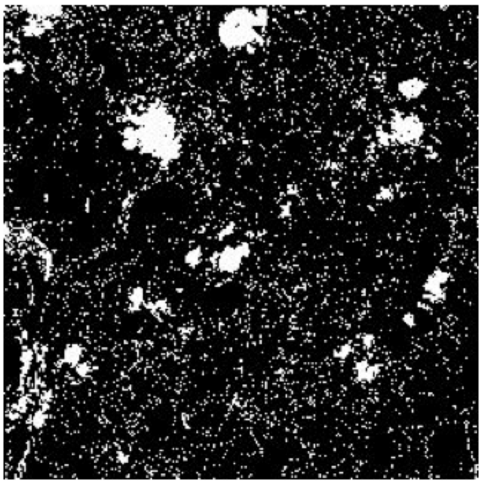

Figure 5. Cloud mask generated for the Landsat-7

shown in Figure 3(a)

3.5 Web interface

It doesn't matter if a project has the best data in the world, if the users cannot find what they need quickly and easily, it won't get used. IMAGESEER provides a modern and graphically-rich web site for easily browsing and downloading all of the selected datasets, truth data, and tutorials. Using a paradigm common on commercial websites, users can restrict their searches by selectively filtering by data source (project, mission, and instrument), region of interest, desired image processing technique, and time period.

The IMAGESEER web site provides access to three elements:

- Education (Imagepedia and Resources)
- Account Maintenance
- Mission Scenes and Benchmark Truth Data

Every IMAGESEER web page contains a horizontal menu bar allowing the user to access these three elements.

3.5.1 Education

The Educational portion of the site is divided into the Imagepedia and Resources. Imagepedia is a collection of documents that provide a general overview of what is Image Processing, what is Remote Sensing and what it means to apply general image processing techniques to remotely sensed imagery. Some of these documents are short articles providing general introductions; others are longer articles with in-depth technical details and lessons learnt. A few topics are also presented as PowerPoint tutorials. We anticipate that this collection will evolve over time and will become a trusted reference for students, teachers and researchers alike to find information useful for study, lessons and research questions. The Resources section provides access to source code, algorithms, and other Image Processing software useful to IMAGESEER users.

3.5.2 Account Maintenance

IMAGESEER is designed to be easy to use and to avoid raising any barriers to its use. Specifically, this means that a user is not required to create an account or to log in. The user can access all the data on the web site, including reading articles, browsing the scene database, and downloading image files and truth data without logging in. The single feature provided by creating an account is to be able to download the cart as one large zip file; in this case, the user can bookmark several scenes and files by adding them to a cart. Users can either download each individual file one by one by repetitively clicking the download button, or they can create an account, login, and then download the cart as one large zip file.

If the user chooses to create an account, IMAGESEER only requires a simple "proclaimed" user account. The only required information is the user's email address. All other information, e.g., name, address, university affiliation, etc, is optional. Any information entered is kept confidential, cannot be seen by other users, and will only be used for statistical purposes. The IMAGESEER Account Maintenance section is accessed by click the "My Account" menu item. From here, the users can view and change their personal information and also view a history of their actions. It might also prove useful for future uses of IMAGESEER, if Image Processing teachers wish to create and share lesson plans utilizing specific scenes from the database.

3.5.3 Browsing mission and benchmark truth data

The main IMAGESEER page allows the users to select a science domain, e.g., Earth Science. Once this domain is chosen, IMAGESEER displays this Science domain portal page, e.g. the Earth Science portal: see Figure 6. This page displays an Earth Science scene chosen at random from the IMAGESEER database as well as links for jumpstarting the users' browsing. The users can then browse the IMAGESEER database by projects, missions, or instruments. Alternatively, they can also directly browse by Image Processing Technique, specific missions, and geography.

The bulk of the web site is then the filtered Scene List web page, according to the users' choices: see Figure 7. On this page, to the left, users can selectively filter a list of applicable scenes by selecting projects, missions, and instruments, as well as time periods, geographical regions and image processing technique. On the right, the users see a list or table of scenes that match their selected filters, including the associated information, names, keywords, acquisition date (by the satellite), as well as associated mission and instrument. The list can be sorted by clicking on the column headings at the top of the table. The Up/Down arrow indicates the order of the sort as well as which column is being used for the sort. Clicking the arrow reverses the order of the sort. By clicking on the scene thumbnail, name, or More Information button, the users are taken to the "Scene Information" page where they can get more details about the scene. The Scene Information Page (see Figure 8) displays the complete information about a scene, including metadata such as size and latitude/longitude, what files or bands it is composed of, and finally the associated truth data that is available, such as Cloud Masks and NLCD files. On this page, the users can bookmark or add to the cart the individual band files (including raw or GeoTIFF files), truth data, and/or the entire scene. Individual band files can also be downloaded directly from this page.

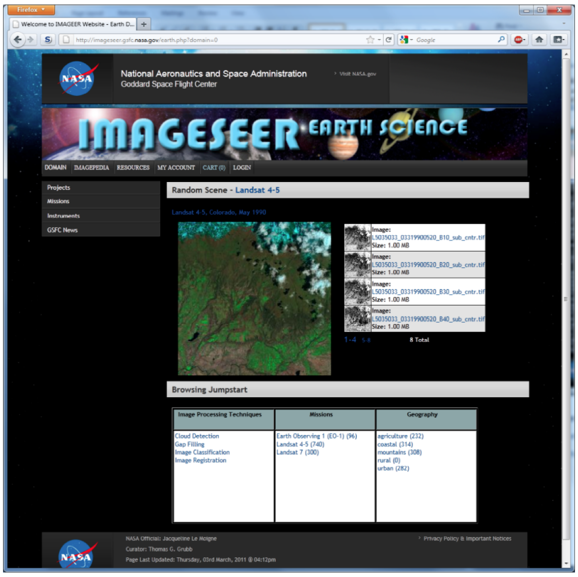

Figure 6. IMAGESEER Earth Science Portal Page

Figure 7. IMAGESEER Filtered Scene List

IMAGESEER allows a user to bookmark scenes and files by adding them to a cart. The Add button available from the Scene Information Page or the Benchmark Page adds the associated file/scene/truth data to the cart. The cart (see Figure 8) keeps a record of all bookmarks for the current session, including which files were bookmarked, their type (scene, file, benchmark data), and their size. Each individual file can be downloaded by clicking the bookmark and then clicking the appropriate download button. At any time, individual items can be removed from the cart as well as the whole cart may be emptied.

Figure 8. Scene Information Page

Figure 9. IMAGESEER Cart

4. CONCLUSION

In this paper, we have described the prototype IMAGESEER database and user interface aiming at distributing easy to use benchmark data for teaching and validating new and existing image processing algorithms. Future work will include populating the database with additional Earth Science data (e.g., MODIS and SeaWIFS), as well as additional applications and data, especially as they relate to Planetary and Exploration Science. In particular, we will acquire and ingest planetary data from the Moon and from Mars, as well as exploration data from the JPL Mars Exploration Rover (MER) missions. For planetary data, some of the Science applications of interest are crater detection and counting, boulder detection and counting, image registration and mineralogy or classification. In the exploration framework, we will consider other Computer Vision techniques corresponding to applications of interest, e.g., obstacle avoidance, i.e., the identification of topographic hazards as they relate to the dimensions and the navigational capabilities of the rovers, and path planning, when considering a sequence of successive images. At the same time, we hope to expand the collection of Imagepedia articles to include: more detailed information about different image processing techniques, such as wavelets or specific edge detection, image segmentation or image classification techniques (e.g., Canny edge detection, region growing segmentation, ISODATA clustering, neural network classification, etc.); information related to the missions, instruments and data utilized for planetary science and exploration applications; and any additional topics requested through users (e.g., university professors and students) feedback. In all cases, we will utilize images from the database for illustrating all Imagepedia articles. Additionally, we will provide the possibility for users to create articles (similarly to Wikipedia) that will be reviewed by our team and by appropriate NASA scientists and university computer science teachers, as needed, before being posted on the IMAGESEER website.

One of the major challenges facing the field of computing today is that the computers have ceased becoming faster, but are instead becoming wider; instead of the steady growth in clock speeds, we are now moving towards an increasing number of processing cores. This fundamental paradigm shift in computing coupled with the sheer amount of imaging data being generated by NASA missions makes it critical for educators to revisit how traditional courses on visual computing are being taught. We expect that our work on IMAGESEER will inform the design of coursework at the universities and in turn will be informed by the cutting-edge research in terascale to exascale computing being conducted in the universities. The hope is that IMAGESEER will be used to develop a number of lesson plans to accompany data sources in IMAGESEER that will address critical issues such as effectively programming hundreds to thousands of computing cores, minimizing data movement, working with I/O limited processing, and techniques that enhance coherence and minimize memory footprint.

The impact of IMAGESEER will be the strongest in Higher Education as it relates to the teaching of Image Processing and Visual Computing in undergraduate and graduate university courses, as well as to the design of new Masters and PhD topics. In particular, with the involvement of NASA Goddard scientists (and potentially of other NASA Centers in the future), these research topics will be carved out of specific challenges posted on the IMAGESEER website by the NASA scientific community with associated data and challenge-specific information.

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NASA IMAGESEER:
NASA IMAGEs for Science, Education, Experimentation and Research

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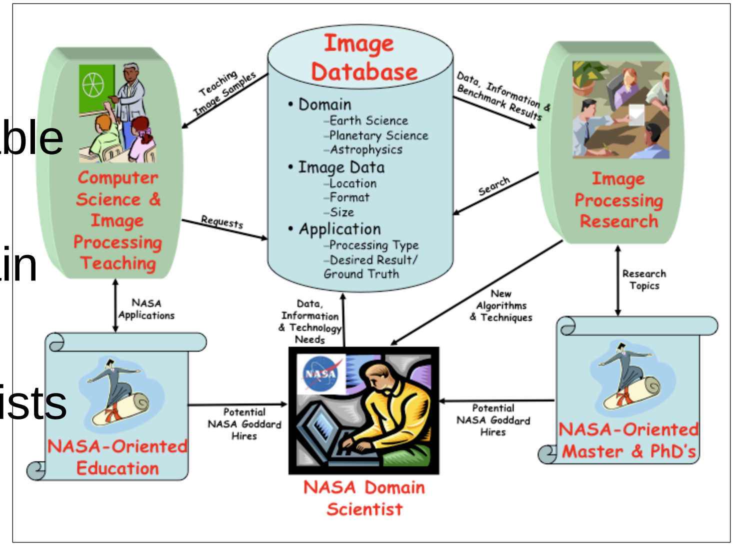
Background

- Large amount of NASA data
- Multiple Science domains: Earth, Astrophysics, Heliophysics, Planetary
- Multiple Application domains: Science models and data assimilation (e.g., Climate models), Exploration (e.g., Moon, Mars, asteroids), Applied Sciences (e.g., disaster management, water resources, invasive species)
- Challenges of NASA data:
  - Variety of sensors and various acquisition conditions
  - Data size and format
  - Lack of a known image model
  - Application domain knowledge
  - Ground Truth or “truth data”

Objective and Approach

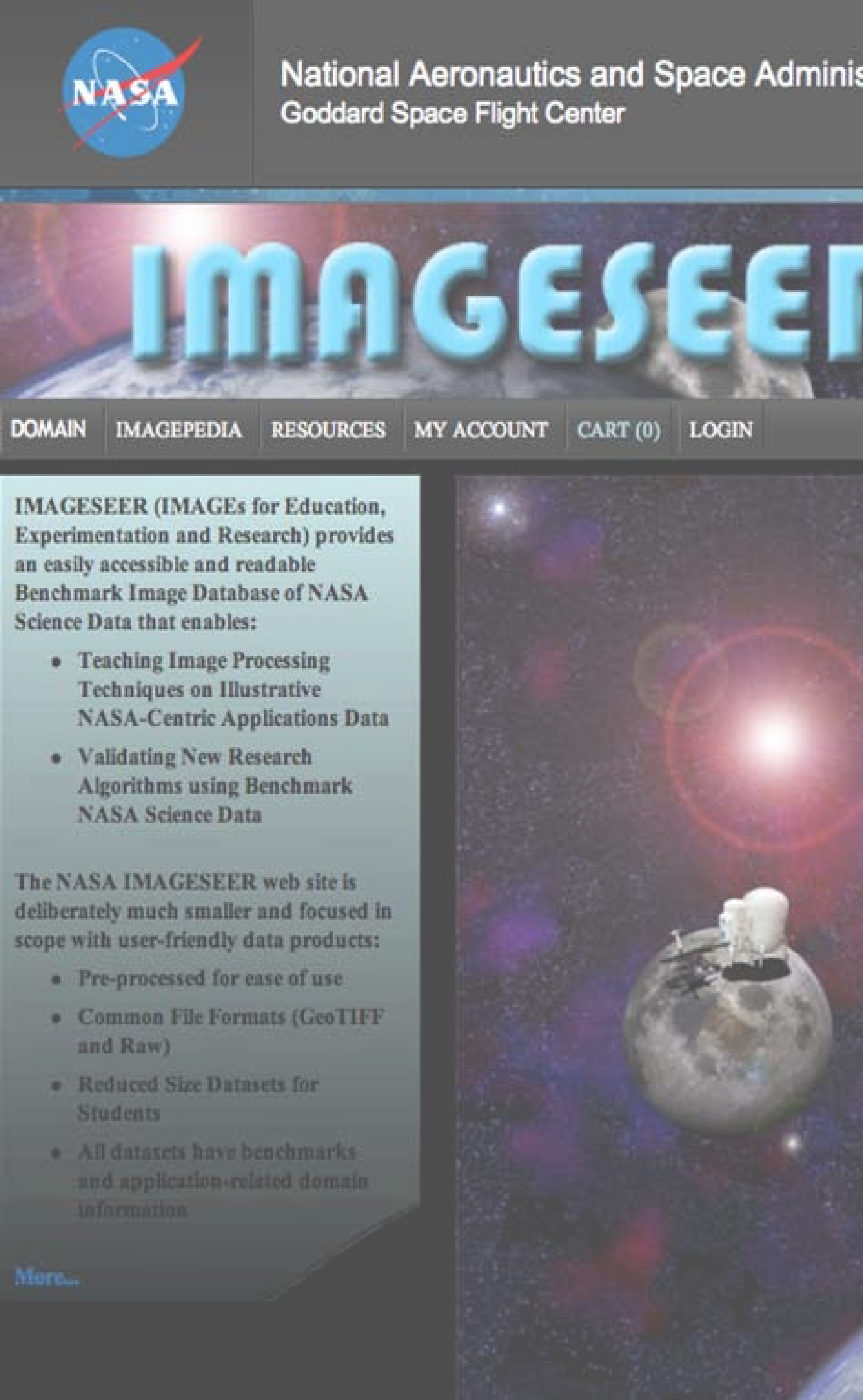
- Objective - Design a database of NASA benchmark image data to:
  1. Enable teaching Image Processing techniques on illustrative NASA-centric applications data
  2. Provide benchmark NASA science data for new research algorithms
  3. Foster Image Processing collaborations between NASA Goddard and university/industry research groups

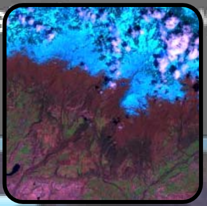
- Approach
  - Each dataset stored in 2 easily readable formats
  - Basic knowledge of application domain
  - Associated “truth data”
  - Challenges defined by domain scientists



Need for a NASA-Centric Image Database

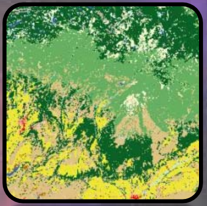
- Non-NASA data, e.g.:
  - ImageProcessingPlace.com Listing of benchmark image datasets
  - CMU Computer Vision Test Images
  - USC Signal and Image Processing Image Database
- Image databases containing NASA data:
  - Large repositories aimed at domain Scientists:
    - NASA Distributed Active Archive Centers (DAAC's)
    - UMD Global Land Cover Facility (GLCF)
    - NASA Planetary Data System (PDS)
    - USGS Earth Resources Observation and Science (EROS) Center
  - Smaller image data collections/image galleries aimed at public outreach:
    - NASA Image Exchange (NIX) (all NASA data)
    - NASA JPL Photojournal (planetary data)
  - No validation data, little or no educational material





Multiple Satellite Data

Cloud Cover Masks

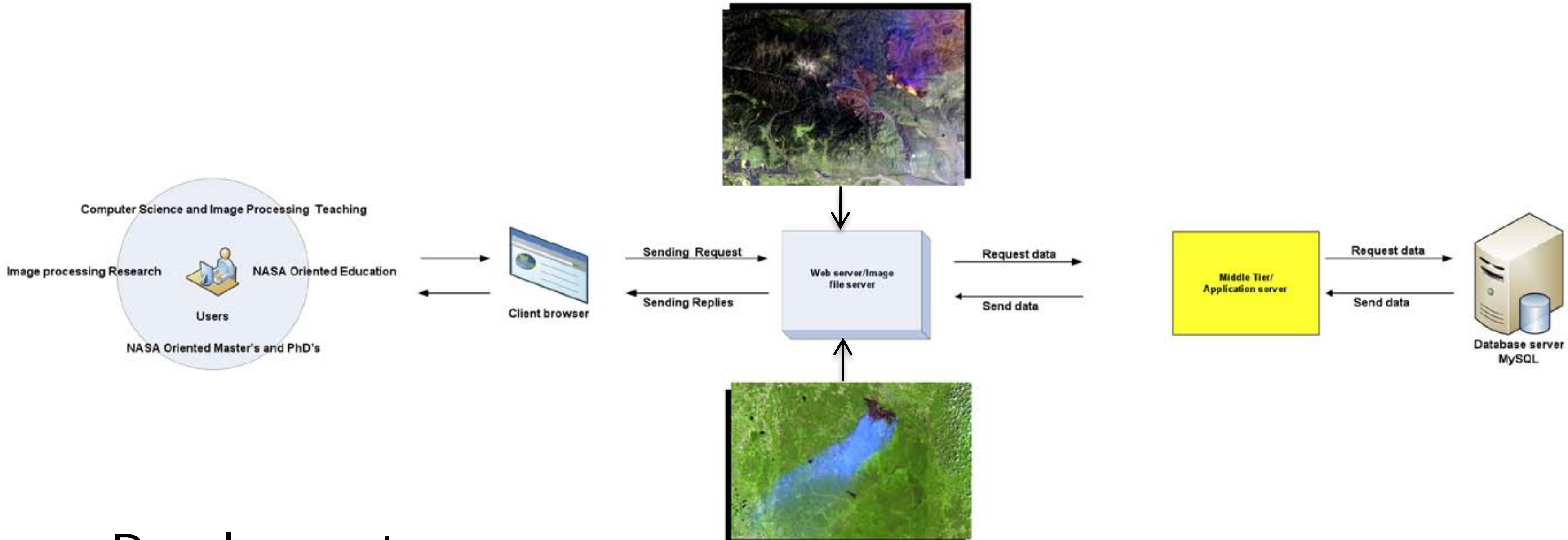


National Land Cover Database Images

Geo-Registered Satellite Data

Imagepedia – Tutorials and Lessons

IMAGESEER Description



- Development:
  - Database built using MySQL database with 27 tables
  - Website developed using Hyper Text PreProcessor (PHP)
  - Format conversion and pre-processing using Python scripts

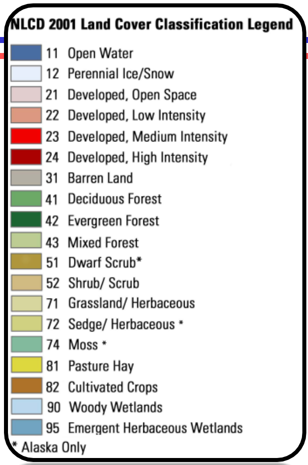
- Four pieces of information compiled for the database:
  1. Scenes
  2. Scene files
  3. Truth data
  4. Interconnections between 1, 2 and 3

IMAGESEER Content

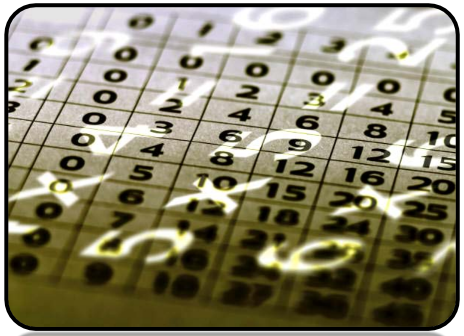
- First version focuses on Earth Science
- Image Processing Problems:
  - Map cover/Classification
  - Cloud detection
  - Image registration
  - *Gap filling/In-painting*
- Regions of interest:
  - Mountainous area: Colorado
  - Urban area: Los Angeles
  - Water-coastal area: Chesapeake Bay
  - Agriculture area: Quincy, Illinois
- Instruments of interest:
  - Landsat-5/Thematic Mapper (TM) (Multispectral; 7 bands)
  - Landsat-7/Enhanced Thematic Mapper (ETM+) (Multispectral; 8 bands)
  - Earth Observing-1 (EO-1)/Advanced Land Imager (ALI)
  - Earth Observing-1 (EO-1)/Hyperion (Hyperspectral; 220 bands)
  - *MODerate resolution Imaging Spectroradiometer (MODIS) (Multispectral; 36 bands)*
  - *Sea-viewing Wide Field-of-view Sensor (SeaWIFS) (Multispectral; 8 bands)*
- Datasets sizes: - Preview (thumbail); - 1Kx1K; - full scenes
- Datasets formats: - GeoTIFF format; - raw data
- Security and Privilege related issues

Example – Benchmark Data for Image Classification

Landsat 5 Bands



NLCD Classification Scheme



Classification Algorithm

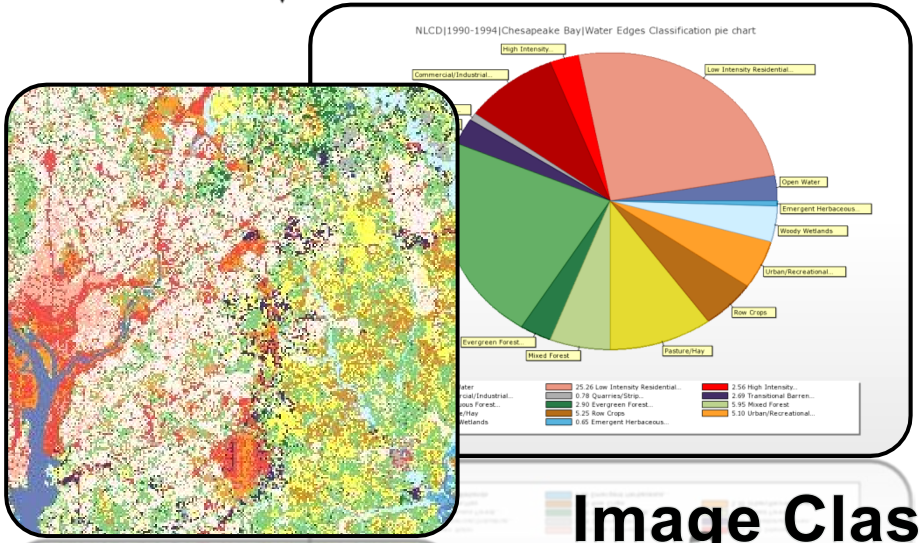


Image Classification

Image Classification seeks to use satellite imagery data to identify or classify the features (trees, grass, road, etc) on the ground.

NLCD (National Land Cover Data) maps gathered in 1992 and 2001 by the Multi-Resolution Land Characteristics Consortium (MRLC) are used as truth data for classification

IMAGESEER provides not only selected satellite data but geo-registered ground truths or benchmarks for image classification and cloud cover detection.

NASA Data Simplified

- Earth Observing System (EOS) data products level characterization: Levels 0, 1A, 1B, 2, 3 and 4
- Landsat:
  - Level 1G: Systematic corrected single scene
  - Level 1T: Terrain corrected single scene (used in IMAGESEER)
  - Level L1Gt: Systematic terrain corrected scene
- EO1:
  - Level L1Gs: Radiometrically corrected, resampled after geometric correction and registered to map projection
  - Level L1Gst: Radiometrically corrected, resampled after geometric correction, registered to map projection, and orth-corrected using Digital Elevation Models (DEMs) (used in IMAGESEER)
- NLCD maps from 1992 and 2001 (before 2006 available)
  - Data relative to NLCD-1992 collected in 1990 through 1994
  - Data relative to NLCD-2001 collected in 1999 through 2003

(assumes changes minimal in 2-year timeframe)

NASA Data Simplified (cont.)

- Total of 8 NLCD maps (2 for each of the 4 geographic locations)
- NLCD maps re-projected from Albers Conic Equal Area (NAD 83) projection to Universal Transverse Mercator (UTM) (WGS84) projection (to match Landsat and EO-1 projections)
- Pre-processing:
  - Geo-register original scenes to corresponding NLCD maps
  - Extract from original scenes portion of the scene matching the NLCD map (according to (lat,long) coordinates)
  - Process geo-registered extracted scenes with cloud detection algorithm, appropriate to acquisition instrument
  - Convert original, geo-registered and extracted scenes as well as cloud masks to 2 common formats, GeoTIFF and raw
  - Extract 1024X1024 scenes from center of geo-registered scenes
  - Create thumbnail of original scenes for browsing purposes

Summary of Current IMAGESEER Data Holdings

Original and Sub-Scenes

Summary of IMAGEER Collection:

Date of compilation: 2011-01-27 (Number c

Scene Collection:	Totals	sub-totals	1990	1991	1992	1993	1994	1999	2000	2001	2002	2003
LandSat 7	302											
Chesapeake Bay (015033)		80	0	0	0	0	0	10	22	20	20	8
Agriculture (025032)		66	0	0	0	0	0	12	14	16	18	6
Mountains (035033)		86	0	0	0	0	0	16	22	18	22	8
Urban (041036)		70	0	0	0	0	0	10	20	14	20	6
LandSat 4-5	741											
Chesapeake Bay (015033)		183	15	24	10	26	24	20	20	12	14	18
Agriculture (025032)		164	14	20	14	10	20	14	16	20	18	18
Mountains (035033)		210	16	16	22	24	24	24	24	24	18	18
Urban (041036)		184	16	18	22	20	12	18	18	22	16	22
EO-1 ALI	30											
Chesapeake Bay (015033)		22	0	0	0	0	0	0	0	3	6	13
Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
Mountains (035033)		2	0	0	0	0	0	0	0	0	1	1
Urban (041036)		6	0	0	0	0	0	0	0	3	0	3
EO-1 Hyperion	17											
Chesapeake Bay (015033)		6	0	0	0	0	0	0	0	4	2	0
Agriculture (025032)		1	0	0	0	0	0	0	0	1	0	0
Mountains (035033)		2	0	0	0	0	0	0	0	0	1	1
Urban (041036)		8	0	0	0	0	0	0	0	7	0	1
TOTAL Scene Collection:	1090											

Summary of Current IMAGESEER Data Holdings (2)

Map Data and Cloud Masks

Ground Truth Images:	Totals	sub-totals	1990	1991	1992	1993	1994	1999	2000	2001	2002	2003
NLCD												
Chesapeake Bay (015033)		4	0	0	2	0	0	0	0	2	0	0
Agriculture (025032)		4	0	0	2	0	0	0	0	2	0	0
Mountains (035033)		4	0	0	2	0	0	0	0	2	0	0
Urban (041036)		4	0	0	2	0	0	0	0	2	0	0
TOTAL NLCD	16											

Cloud Masks	Totals	sub-totals	1990	1991	1992	1993	1994	1999	2000	2001	2002	2003
LandSat 7	222											
Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
Agriculture (025032)		66	0	0	0	0	0	12	14	16	18	6
Mountains (035033)		86	0	0	0	0	0	16	22	18	22	8
Urban (041036)		70	0	0	0	0	0	10	20	14	20	6
LandSat 4-5	548											
Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
Agriculture (025032)		154	14	10	14	10	20	14	16	20	18	18
Mountains (035033)		210	16	16	22	24	24	24	24	24	18	18
Urban (041036)		184	16	18	22	20	12	18	18	22	16	22
EO-1 ALI	0											
Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
Mountains (035033)		0	0	0	0	0	0	0	0	0	0	0
Urban (041036)		0	0	0	0	0	0	0	0	0	0	0
EO-1 Hyperion	0											
Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
Mountains (035033)		0	0	0	0	0	0	0	0	0	0	0
Urban (041036)		0	0	0	0	0	0	0	0	0	0	0
TOTAL Cloud Masks	770											

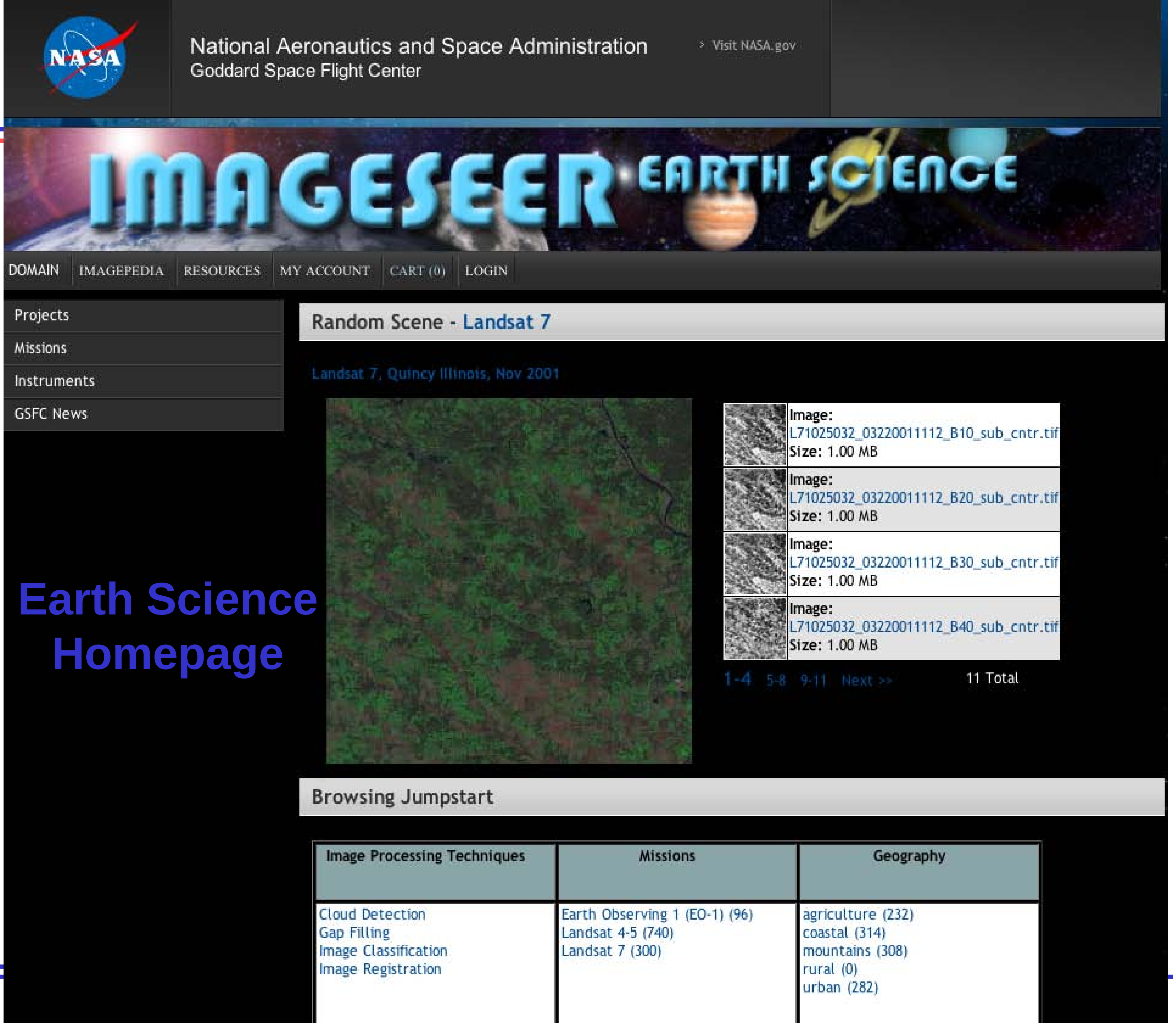
Summary of Current IMAGESEER Data Holdings (3)

Geo-Registered Scenes

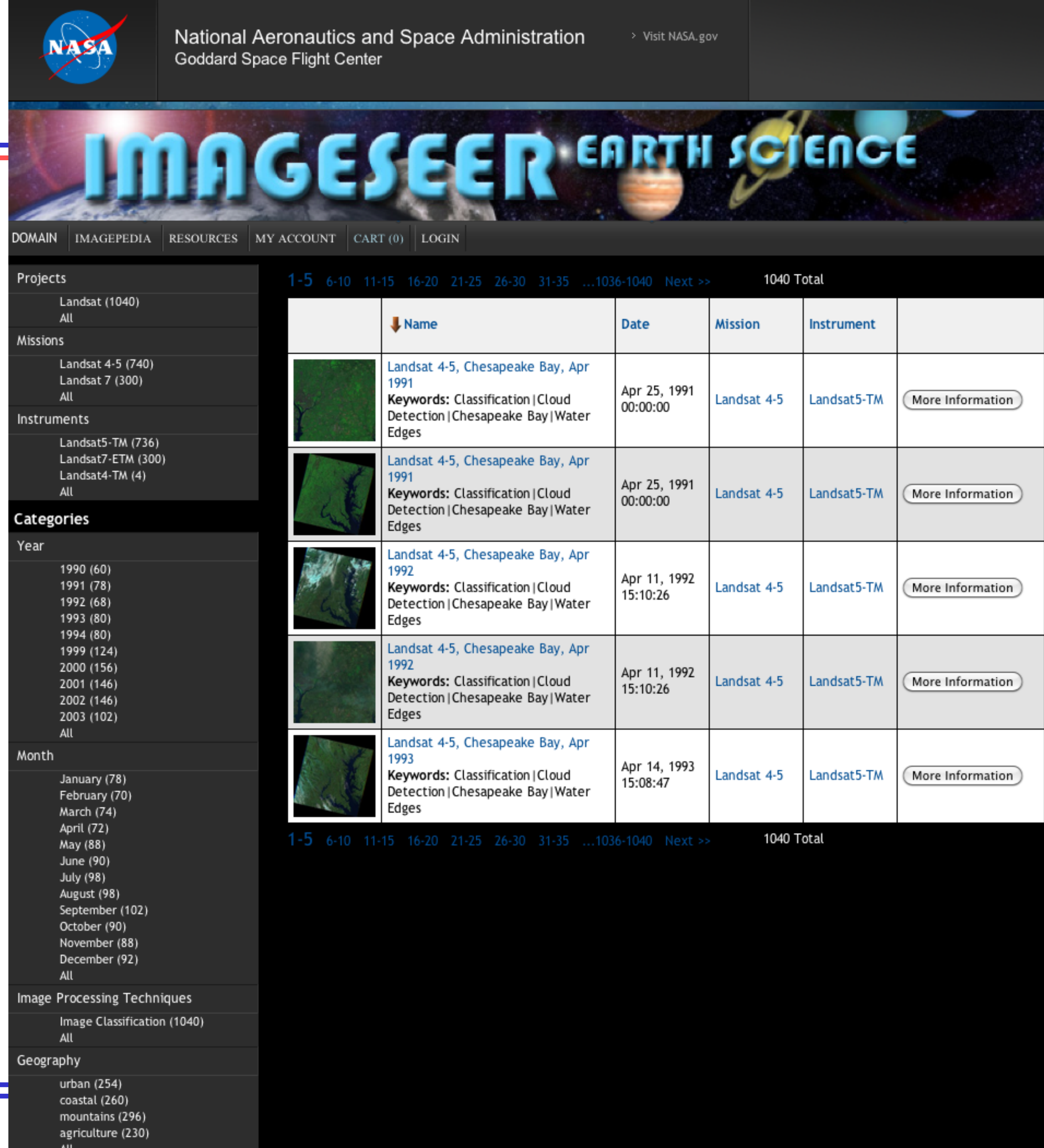
GeoLocated:	Totals	sub-totals	1990	1991	1992	1993	1994	1999	2000	2001	2002	2003
LandSat 7	0											
Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
Mountains (035033)		0	0	0	0	0	0	0	0	0	0	0
Urban (041036)		0	0	0	0	0	0	0	0	0	0	0
LandSat 4-5	0											
Chesapeake Bay (015033)		0	0	0	0	0	0	0	0	0	0	0
Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
Mountains (035033)		0	0	0	0	0	0	0	0	0	0	0
Urban (041036)		0	0	0	0	0	0	0	0	0	0	0
EO-1 ALI	30											
Chesapeake Bay (015033)		22	0	0	0	0	0	0	0	3	6	13
Agriculture (025032)		0	0	0	0	0	0	0	0	0	0	0
Mountains (035033)		2	0	0	0	0	0	0	0	0	1	1
Urban (041036)		6	0	0	0	0	0	0	0	3	0	3
EO-1 Hyperion	17											
Chesapeake Bay (015033)		6	0	0	0	0	0	0	0	4	2	0
Agriculture (025032)		1	0	0	0	0	0	0	0	1	0	0
Mountains (035033)		2	0	0	0	0	0	0	0	0	1	1
Urban (041036)		8	0	0	0	0	0	0	0	7	0	1
TOTAL GeoLocated:	**47**											

IMAGESEER WEB USER INTERFACE

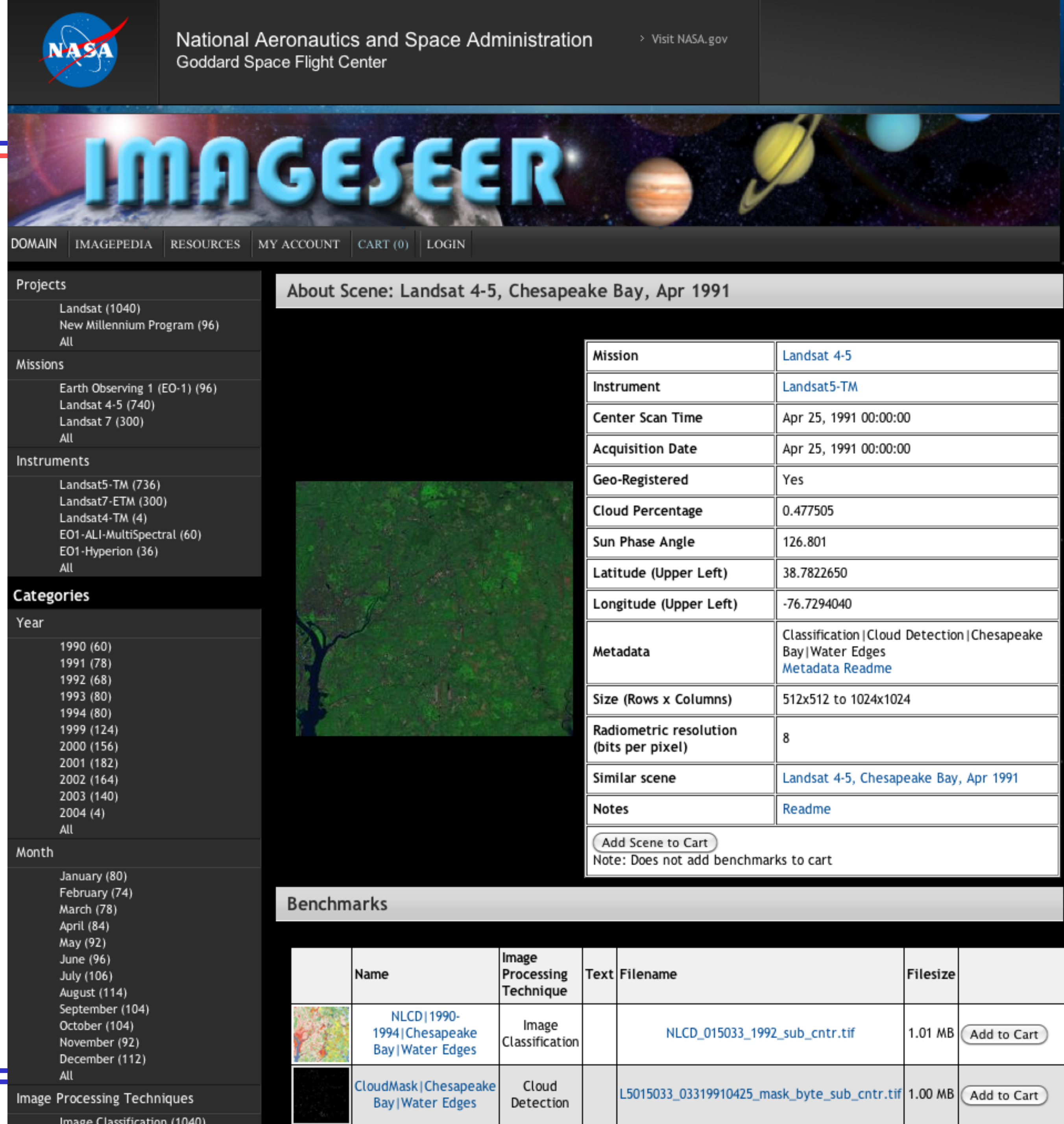
Earth Science Homepage



Selection of Landsat Data with Classification Ground Truth



Scene and Corresponding Data



Scene and Corresponding Data (2)

- June (96)
- July (106)
- August (114)
- September (104)
- October (104)
- November (92)
- December (112)
- All

Image Processing Techniques

- Image Classification (1040)
- Cloud Detection (1030)
- Image Registration (96)
- All

Geography

- urban (282)
- coastal (314)
- mountains (308)
- agriculture (232)
- All

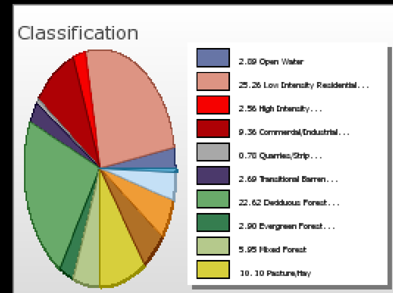
Location

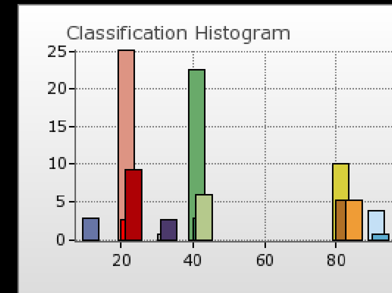
- Chesapeake Bay (314)
- Colorado (308)
- Los Angeles (282)
- Quincy Illinois (232)
- All

GSFC News

	Name	Image Processing Technique	Text	Filename	Filesize	
	NLCD|1990-1994|Chesapeake Bay|Water Edges	Image Classification		NLCD_015033_1992_sub_cntr.tif	1.01 MB	Add to Cart
	CloudMask|Chesapeake Bay|Water Edges	Cloud Detection		L5015033_03319910425_mask_byte_sub_cntr.tif	1.00 MB	Add to Cart

More information on NLCD Image Classification...





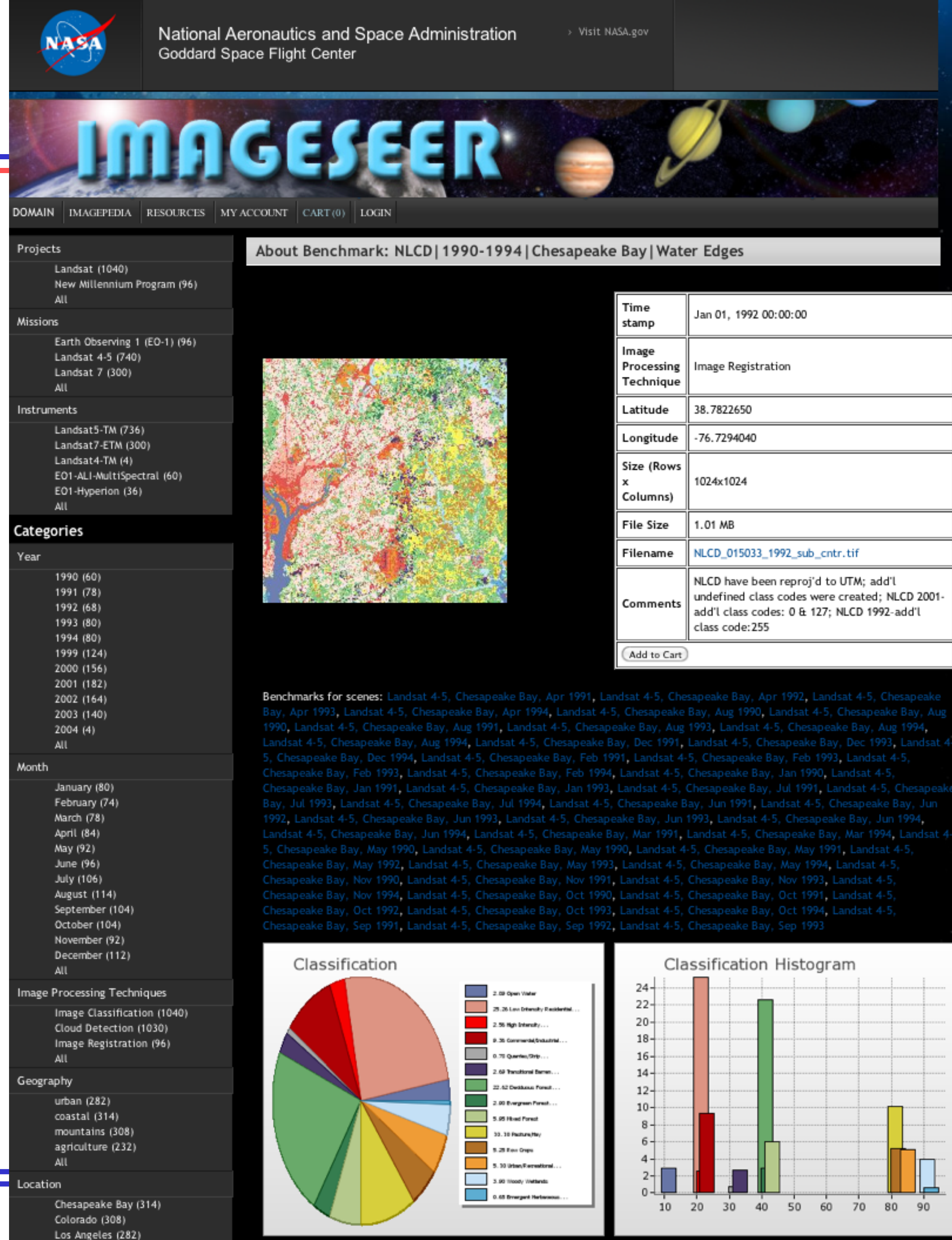
Scene Band Files

1-5 6-8 8 Total

	Band	Filename	Size (TIF/Raw)	Spatial Resolution (meters)	TIF / Raw
	10	L5015033_03319910425_B10_sub_cntr.tif (Raw) **Rows x Cols:** 1024x1024	1.00/1.00 MB	30	Add to Cart RAW Download RAW
	20	L5015033_03319910425_B20_sub_cntr.tif (Raw) **Rows x Cols:** 1024x1024	1.00/1.00 MB	30	Add to Cart RAW Download RAW
	30	L5015033_03319910425_B30_sub_cntr.tif (Raw) **Rows x Cols:** 1024x1024	1.00/1.00 MB	30	Add to Cart RAW Download RAW
	40	L5015033_03319910425_B40_sub_cntr.tif (Raw) **Rows x Cols:** 1024x1024	1.00/1.00 MB	30	Add to Cart RAW Download RAW
	50	L5015033_03319910425_B50_sub_cntr.tif (Raw) **Rows x Cols:** 1024x1024	1.00/1.00 MB	30	Add to Cart RAW Download RAW

1-5 6-8 8 Total

Truth Data/NLCD Map Data



Truth Data/Cloud Mask

National Aeronautics and Space Administration
Goddard Space Flight Center

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Projects
- Landsat (1040)
- New Millennium Program (96)
- All

Missions
- Earth Observing 1 (EO-1) (96)
- Landsat 4-5 (740)
- Landsat 7 (300)
- All

Instruments
- Landsat5-TM (736)
- Landsat7-ETM (300)
- Landsat4-TM (4)
- EO1-ALI-MultiSpectral (60)
- EO1-Hyperion (36)
- All

Categories

Year
- 1990 (60)
- 1991 (78)
- 1992 (68)
- 1993 (80)
- 1994 (80)
- 1999 (124)

About Benchmark: CloudMask | Chesapeake Bay | Water Edges

Time stamp	Dec 31, 1969 19:00:00
Image Processing Technique	Image Registration
Latitude	38.7822650
Longitude	-76.7294040
Size (Rows x Columns)	1024x1024
File Size	1.00 MB
Filename	L5015033_03319910425_mask_byte_sub_cntr.tif
Comments	Cloud mask/percentage calculated using LDCM's ACCA program
Add to Cart	

Benchmarks for scenes: Landsat 4-5, Chesapeake Bay, Apr 1991

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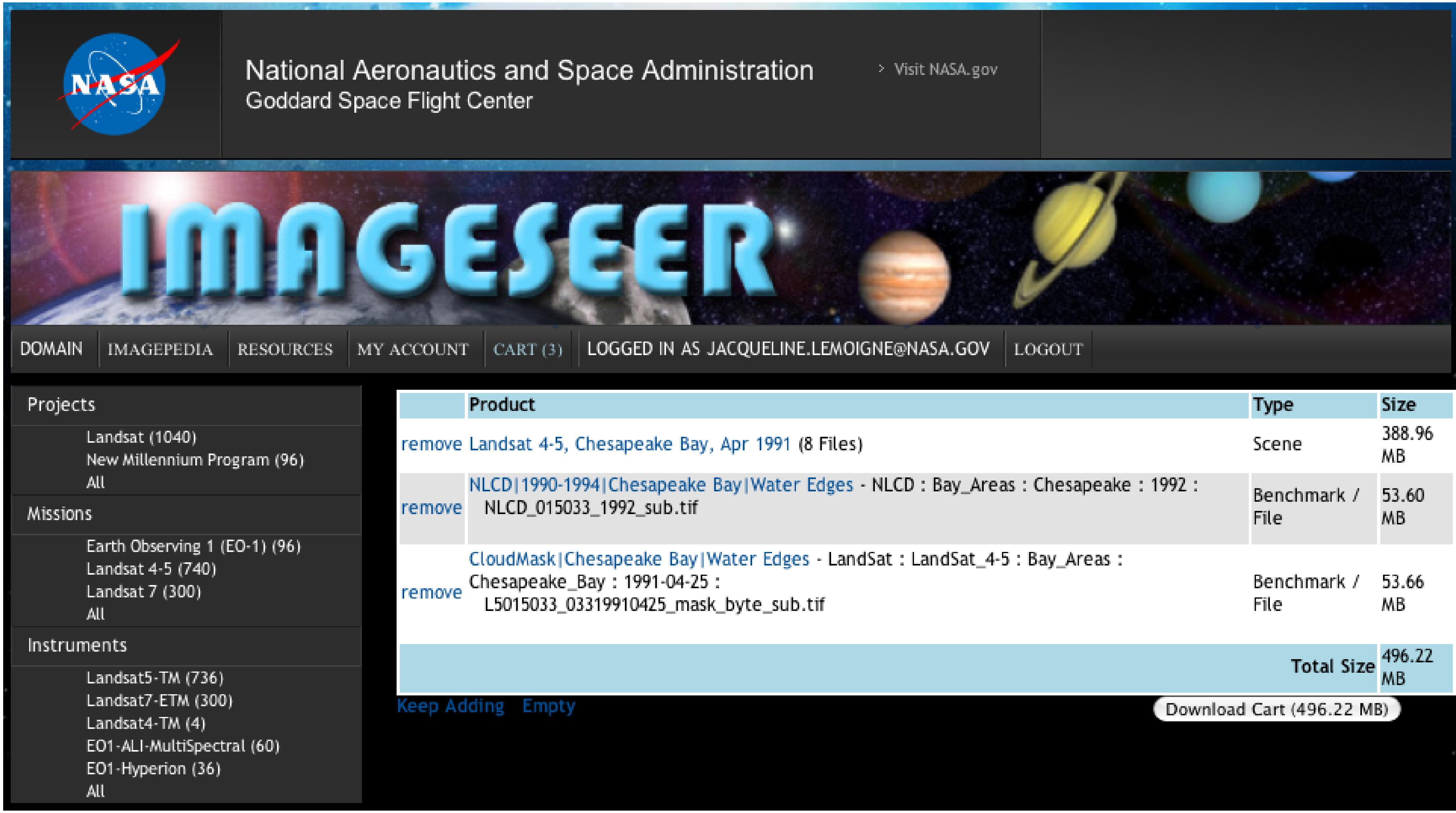

Imagepedia/Education

National Aeronautics and Space Administration
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- Instruments
- GSFC News

Imagepedia is a collection of documents that provide a general overview of what is Image Processing, what is Remote Sensing and what it means to apply general image processing techniques to remotely sensed imagery. Some of these documents are short articles providing general introductions, or longer articles with in-depth technical details and lessons learnt. A few topics are also presented as power point tutorials.

We anticipate that this collection will evolve over time and will become a trusted reference for students, teachers and researchers alike to find information useful for study, lessons and research questions.

If you would like to contribute an article, please send us an email (contact information on the website).

Categories: Educational, General, Tutorial, All

1-10 11-12 12 Total

Title: Edge- and Wavelet-Based Image Registration
Author: Jacqueline Le Moigne (USRA/CESDIS) , Nazmi El-Saleous (University of Maryland), Eric Vermote (University of Maryland)
Category: Educational

Most automatic registration methods are either correlation-based, feature-based, or a combination of both. Examples of features which can be utilized for automatic image registration are edges, regions, corners, or wavelet-extracted features. In this paper, we describe two proposed approaches, based on edge or edge-like features, which are very appropriate to highlight regions of interest such as coastlines. The two iterative methods utilize the Normalized Cross- Correlation of edge and wavelet features and are applied to such problems as image-to-map registration, landmarking, and channel-to-channel co-registration, utilizing test data, AVHRR data, as well as GOES image data.

Title: General Introduction to Image Processing for Remote Sensing
Author: Devin Miller (Eastern Michigan University, NASA Intern) & Jacqueline Le Moigne (NASA GSFC)
Category: Educational

As an instrument scans a surface, it generates an image. Although the raw image is important in its own right, it contains a number of flaws inherent to the system that generated the image. For instance factors such as stochastic fluctuations in the detector's signal response known as electronic noise and the detector's spectral efficiency may affect how the image varies from the "true" scene on a pixel-by-pixel basis. Likewise, factors such as the detector's orientation in space relative to the area being observed, the refraction of light as it travels through the atmosphere, the occlusion of small areas in the scene by geological features like mountains that vary surface height dramatically, as well as other effects such as clouds, shadows, air pollution, or data acquisition at night time versus day time, may cause the acquired image not to be completely accurate, geometrically. Therefore, to take into account these different effects, it is important to look at Remotely Sensed Image Processing as a series of pre-processing, processing and analysis steps modeled after multiple disciplines

Conclusion/Future Work

- First prototype of IMAGESEER database and user interface
  - Beta-test started and comments welcome!

    imageseer.nasa.gov

- Future work:
  - Additional Earth Science data (e.g., MODIS and SeaWIFS)
  - Gap filling data
  - Moon and Mars Planetary data for:
    - Crater detection and counting
    - Boulder detection and counting
    - Image registration
    - Mineralogy/classification
  - Exploration data:
    - Obstacle avoidance
    - Path planning
  - Link to enCOMPASS (Educational NASA Computational and Scientific Studies): encompass.gsfc.nasa.gov