

# TerraLook: A GIS-Ready Time-Series of Satellite Imagery

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## Abstract

The goal of TerraLook is to provide satellite images that anyone can use to see changes in the Earth's surface over time. Landsat and other satellites have been collecting images of the Earth from space for more than 35 years. TerraLook allows users to create their own collections of georeferenced simulated natural-color JPEG images from Landsat (circa 1975, 1990, 2000, and 2005) and ASTER (2000 to present) at no charge. The simulated natural colors in TerraLook images are consistently processed so that images from these time periods can be easily compared. TerraLook images are bundled with standards-compliant metadata, a world file, and an outline of each image's ground footprint, enabling their use in Geographic Information Systems and Web mapping applications. Different ArcGIS solutions were developed to use with TerraLook Collections. For ArcGIS and ArcGIS Explorer users, project files are available to permit TerraLook Collections to be easily integrated into GIS projects or educational curricula for visual analysis. A Python script is available to extract vector data, such as country boundaries, protected areas, hydrography, and populated places, from global datasets to create extended TerraLook Collections. Users can add local data, including ground photography, to the TerraLook Collections. These localized collections can be easily shared. An ArcGIS Publisher tool is provided with the ArcMap project file for publishing documents for use with the free ArcReader application.

**Keywords:** TerraLook, Landsat, ASTER, remote sensing, ArcGIS, ArcMap, ArcReader, ArcGIS Explorer, georeferenced simulated natural-color images, land change, GIS.

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

## **Introduction**

Viewing the Earth through satellite imagery can be useful and interesting to many outside of the remote sensing community, including science writers, field scientists, resource managers, policy makers, students, and the general public. TerraLook was developed to broaden the population of satellite image users by providing both Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Landsat data as simulated natural-color JPEG images. TerraLook aims to serve user communities who have a need for images of the Earth but do not have technical remote sensing expertise, time to prepare and organize images for visualization, or access to specialized scientific image processing software. TerraLook Collections, which have been available since 2008, consist of readily usable remotely sensed images designed for visual interpretation and are distributed at no cost to the user. TerraLook Collections will be of value to anyone who wants to see the changes to the Earth's surface since 1972. Users who need to perform digital analysis can acquire the source data. The georeferenced TerraLook product is compatible with most GIS and Web mapping applications. TerraLook Collections can be selected and downloaded at no cost from the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center at <http://terralook.cr.usgs.gov>.

ArcGIS is one of the GIS applications compatible with TerraLook Collections. ArcMap documents, created using ArcObjects and Visual Basic applications, are provided to organize and display TerraLook Collections. Users can add more data to the ArcMap document, and the modified ArcMap document can be shared with other users. The TerraLook Collections include additional information describing the content, quality, type, creation, and spatial information about the collection and the images as metadata to make the spatial information more understandable as a summary document. This metadata can be visualized from ArcMap, ArcCatalog, or a Web browser. ArcGIS compatible projection files are also included in the TerraLook Collections.

In this paper we describe TerraLook Collections and their content, the creation of extended TerraLook Collections, and the use of TerraLook Collections in ArcGIS.

## TerraLook Collection

A TerraLook Collection consists of images derived from two satellite imaging programs:

- Landsat images from the USGS EROS Center archive
- ASTER images from the National Aeronautics and Space Administration (NASA) Land Processes Distributed Active Archive Center (LP DAAC)

Since 1972, a series of Landsat satellites has been collecting digital images of the Earth. The most recent TerraLook release uses the Global Landsat Survey (GLS) data as the Landsat source data. The GLS images were selected from 2.5 million images in the Landsat archive to provide global coverage of the Earth's surface at four epochs of time (circa 1975, 1990, 2000, and 2005). Images for each epoch were selected for best cloud-free coverage during the local growing season. The nominal pixel size is 80 m for the 1975 images and 30 m for the 1990, 2000, and 2005 images. The date range for each of the epochs is listed below:

- 1975: 1972–1987 Multispectral Scanner (MSS)
- 1990: 1987–1997 Thematic Mapper (TM)
- 2000: 1999–2003 Enhanced Thematic Mapper Plus (ETM+)
- 2005: 2003–2008 TM and ETM+

ASTER, one of five sensors on the Terra spacecraft, has captured over 1.5 million images since its launch in 1999. TerraLook images can be derived from any image in this archive from early 2000 to the present to provide the most recent images captured at twice the resolution (15 m) of the Landsat sensors.

The TerraLook images are bundled with image footprint and metadata files that describe the images and the collection. The image footprint files delineate the image boundaries so the image location can be easily seen, and the metadata files contain variables that describe the sensor, acquisition time, and name of each image file. The image footprints are stored as industry-standard GIS shapefiles. The image and collection metadata are stored in standards-compliant XML files. TerraLook products consisting of images, footprints, and metadata are bundled into zip files.

A TerraLook Collection can consist of any combination of ASTER and Landsat GLS images. A common use is the study of the Earth over time; however, many users simply want an image for their area of interest. A typical choice is a collection through time for one or more cities or parks, or for a region or country, but a collection can also consist of images from one sensor for a larger area within the same time period. The selection of images is completely up to the user.

## TerraLook Image

TerraLook images have many advantages. The JPEGs are compressed with a high quality setting, making them quick to download but with few visible compression artifacts.

Simulated natural color makes the imagery easy to understand by a wide range of users. The algorithm used to process TerraLook images permits the creation of a visually consistent time series from the earliest Landsat sensor launched in 1972 to the currently orbiting ASTER and Landsat sensors of today.

TerraLook images are a "simulated natural color" rather than a "true" or "natural" color image. True- or natural-color images are created from blue, green, and red light. Most satellite sensors do not collect data in the blue spectral band of the electromagnetic spectrum. Even when a blue band is available, the blue light, as seen from space, is scattered by atmospheric moisture (the reason for blue skies) creating a very noisy blue band, particularly in humid areas. Most satellite sensors collect near-infrared (NIR) data, which is sensitive to the health of vegetation. In response to the lack of a blue band and the availability of an information-rich NIR band, most satellite images are viewed using some combination of visible and infrared data. TerraLook images use the bands derived from the red, green, and NIR bands collected by the Landsat and ASTER sensors with the algorithm described below to form a simulated natural-color image.

$$\text{Red} = \text{Red}$$

$$\text{Green} = \frac{2}{3} \text{ Green} + \frac{1}{3} \text{ NIR}$$

$$\text{Blue} = \frac{2}{3} \text{ Green} - \frac{1}{3} \text{ NIR}$$

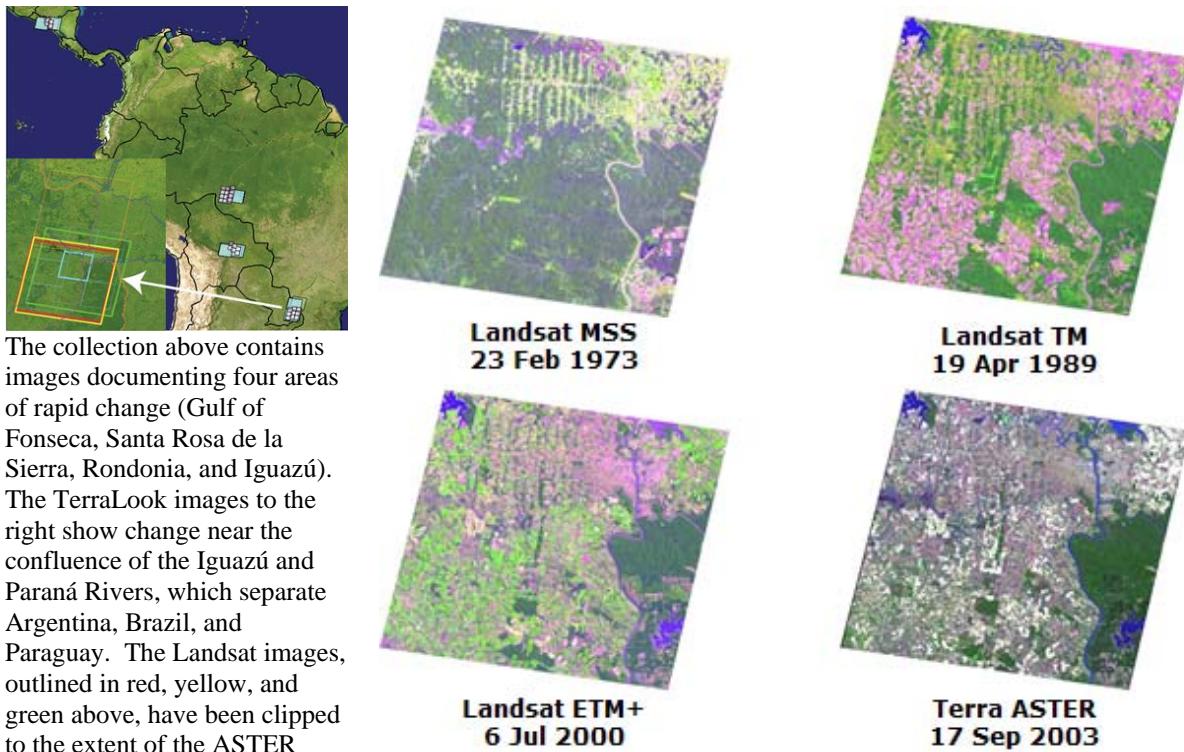
The green band is enhanced through the addition of information from the vegetation-sensitive NIR band to create a synthetic green band. The synthetic blue is created from the green band, which is spectrally most similar to blue, with the vegetation information suppressed.

TerraLook images are georeferenced with industry standard world files, which makes them suitable for use in most Geographic Information Systems, image processing systems, and Web mapping applications. Just as important, the images can be viewed in any software that can read and display JPEG images; this includes most Web browsers, word processors, and graphics packages.

## **The Use of TerraLook Collections to Document Change**

Satellite images provide practical documentation of the Earth through time, but to interpret images requires detective work to understand the underlying causes of the differences. Some changes may be fairly rapid, dramatic, and easily noticed: destruction by flooding, a fire sweeping through a forest or grassland, or the explosive eruption of a volcano. Many differences are more gradual and even anticipated, such as the cyclical variations in the environment that influence numerous aspects of our lives: the alternating wet and dry seasons in tropical and subtropical regions, or the yearly progression of seasonal changes in the middle and higher latitudes. Still other landscape changes occur incrementally and, being less obvious, are detected only over a number of years or even decades: expanses of natural vegetation yielding to agricultural plots, encroaching urbanization transforming farmlands into housing tracts and shopping malls, or the shrinking of lakes as rivers are diverted for agricultural or urban use. Care must be taken

to separate normal variability from fundamental change. For example, TerraLook Collections document the loss of the Paranaenese forest, the increase in agricultural development, and the construction of the world's largest dam at the confluence of the Iguazú and Paraná Rivers (Figure 1).



*Figure 1. Example of a TerraLook Collection to document rapid changes in four areas. TerraLook images show changes near the confluence of the Iguazú and Paraná Rivers.*

## Extended TerraLook Collections

An “Extended TerraLook Collection Generator” ArcGIS tool, available at <http://arcscripts.esri.com/>, has been created that allows ArcGIS users to create Extended TerraLook Collections. The Extended TerraLook Collection Generator adds reference data to the standard TerraLook Collections acquired from USGS EROS to support the visual interpretation of the image time series. A Python script was developed to create extended TerraLook Collections by clipping vector reference data and Digital Elevation Model (DEM) raster data from global datasets. Global and national reference data can be found in the ESRI Data & Maps CD, the gData Web site, the Geo Data Portal Web site, or any other source of global, regional, or national data in shapefile format. The Shuttle Radar Topography Mission (SRTM) DEM data can be downloaded from the Consultative Group on International Agricultural Research - Consortium for Spatial Information (CGIAR-CSI) Web site (Figure 2).

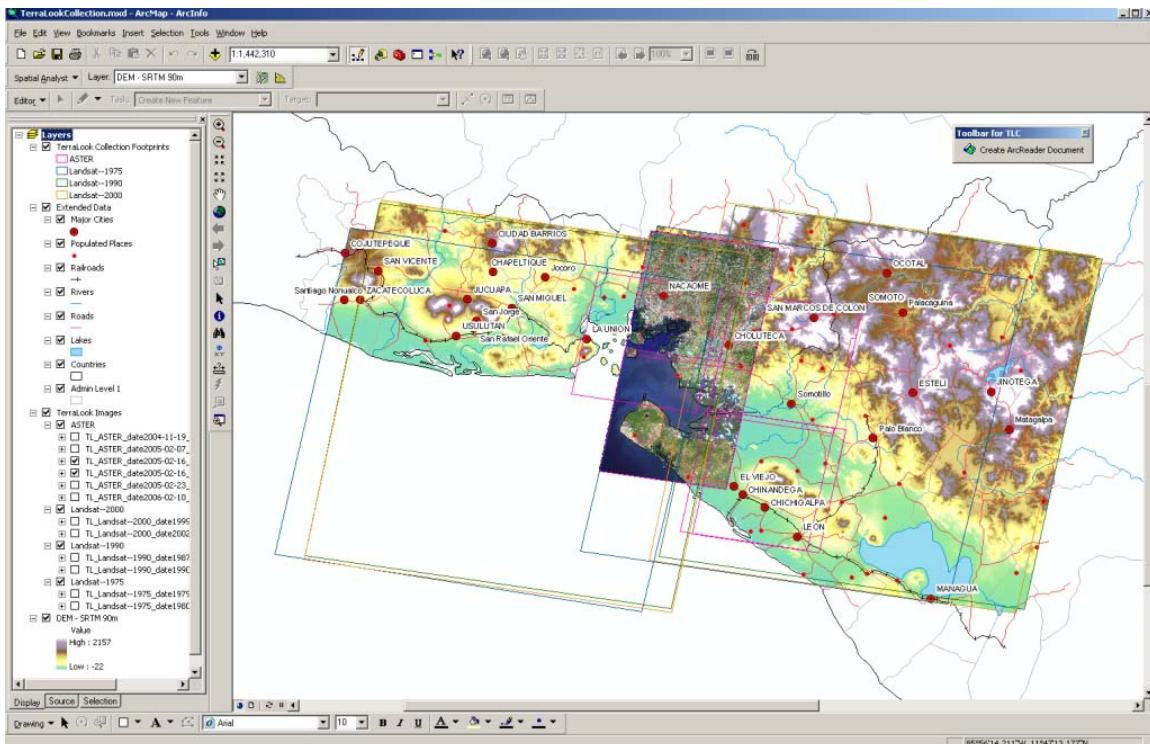


Figure 2. ArcMap document displaying an extended TerraLook Collection. The footprints of the image data are represented by the rectangular image footprints.

The GIS reference data for each layer should have the shapefile name noted in parentheses for use by the Python script: countries (countries.shp), administrative level 1 (admin\_level1.shp), protected areas (national\_protected\_areas.shp, national\_other\_protected\_areas.shp, international\_protected\_areas.shp), lakes (lakes.shp), rivers (river.shp), roads (roads.shp), railroads (railroads.shp), major cities (major\_cities.shp), and populated places (populated\_places.shp) (Figure 3).

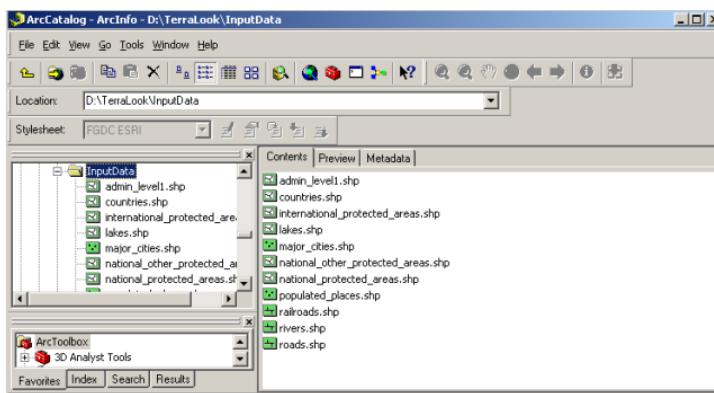


Figure 3. Shapefile names for the reference data used in the ArcMap document for extended TerraLook Collections.

The Python script can be run from the Command Prompt, Python IDE (PythonWin, Python IDLE), or ArcToolbox (Figure 4).

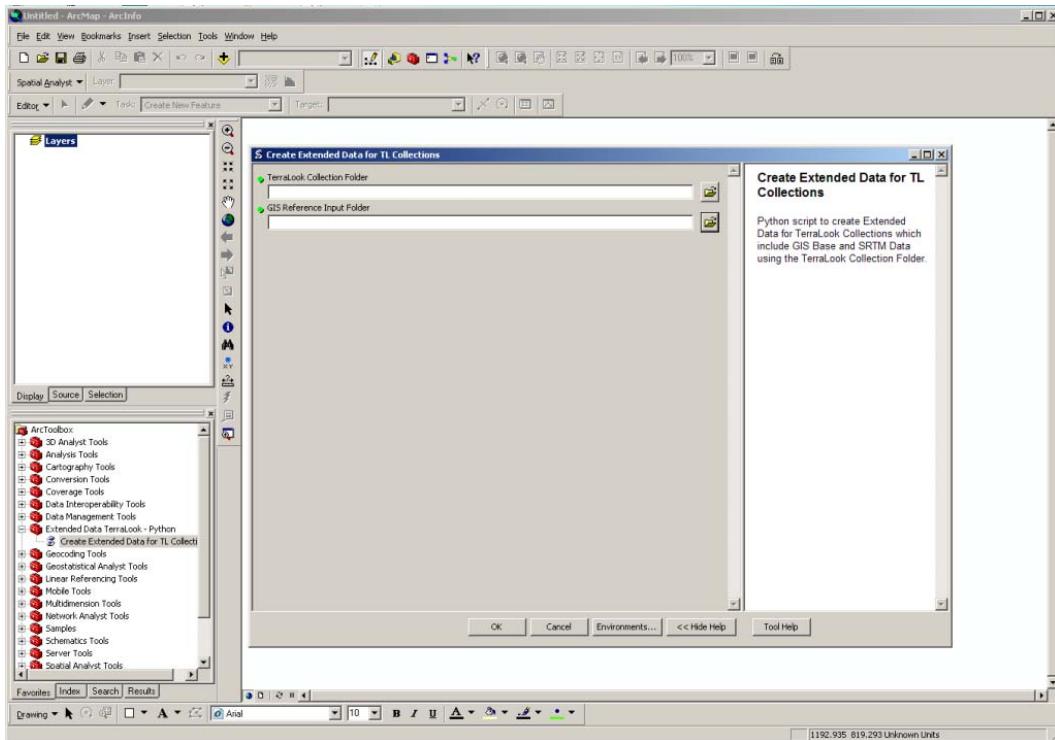


Figure 4. Python script as a tool in ArcToolbox.

These data are added to the standard TerraLook Collection that includes the TerraLook footprints and the TerraLook image data, within “*extdata*” and “*dem*” subdirectories (Figure 5).

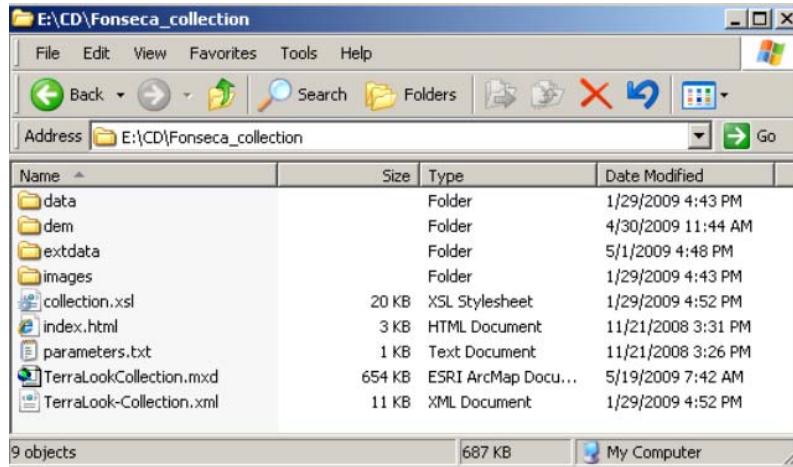


Figure 5. ArcMap document in the TerraLook Collection directory.

## Downloading CGIAR-CSI SRTM 90-m DEM data

The SRTM 90-m DEM data provided by CGIAR-CSI have been processed to fill gaps. These data are provided in an effort to promote the use of geospatial science and applications for sustainable development and resource conservation in the developing

world. The SRTM 90-m DEMs have a resolution of 90 m at the equator and are provided in mosaics of 5- by 5-degree tiles for easy download and use.

The data are available in both ArcInfo ASCII and GeoTiff formats to facilitate their ease of use in a variety of image processing and GIS applications. The DEM data from CGIAR-CSI are available to download from the “SRTM Data Search and Download” page. The user can easily locate an area of interest by using a map or by adding the bounding latitude and longitude coordinates of the TerraLook Collection (Figure 6). The downloaded data must be in the “*dem*” directory of the TerraLook Collection to be processed by the Python script.

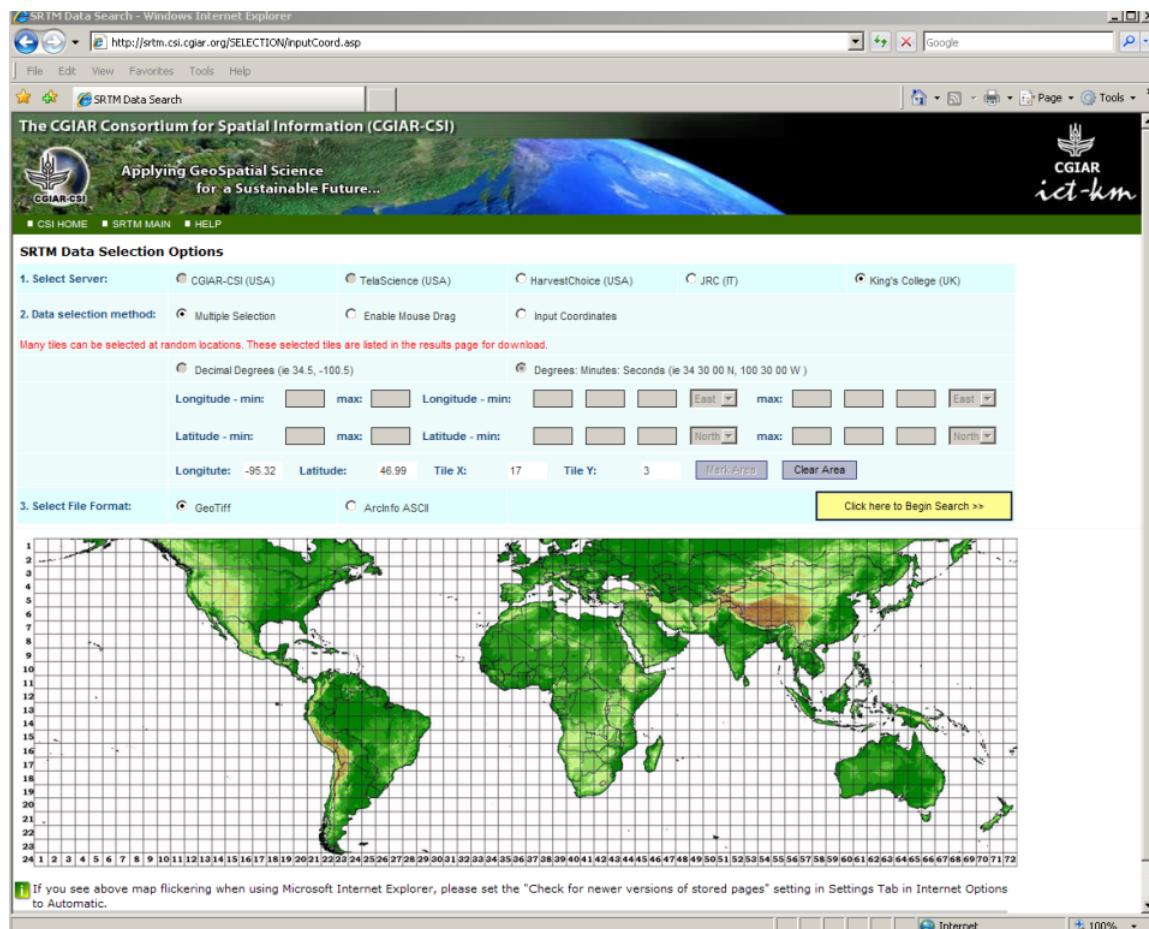


Figure 6. SRTM Data Search page to download DEM data from CGIAR-CSI.

## ArcGIS solutions for TerraLook Collections

TerraLook Collections are bundled with standards-compliant metadata and projections files for the collection, images, and footprints. For each TerraLook Collection, a customized ArcMap document (MXD File) is created to allow users to easily open and analyze TerraLook Collections in ArcMap. The customized ArcMap document, created using Visual Basic Application embedded in ArcMap and ArcObjects, displays a TerraLook Collection with or without extended data (Figure 7).

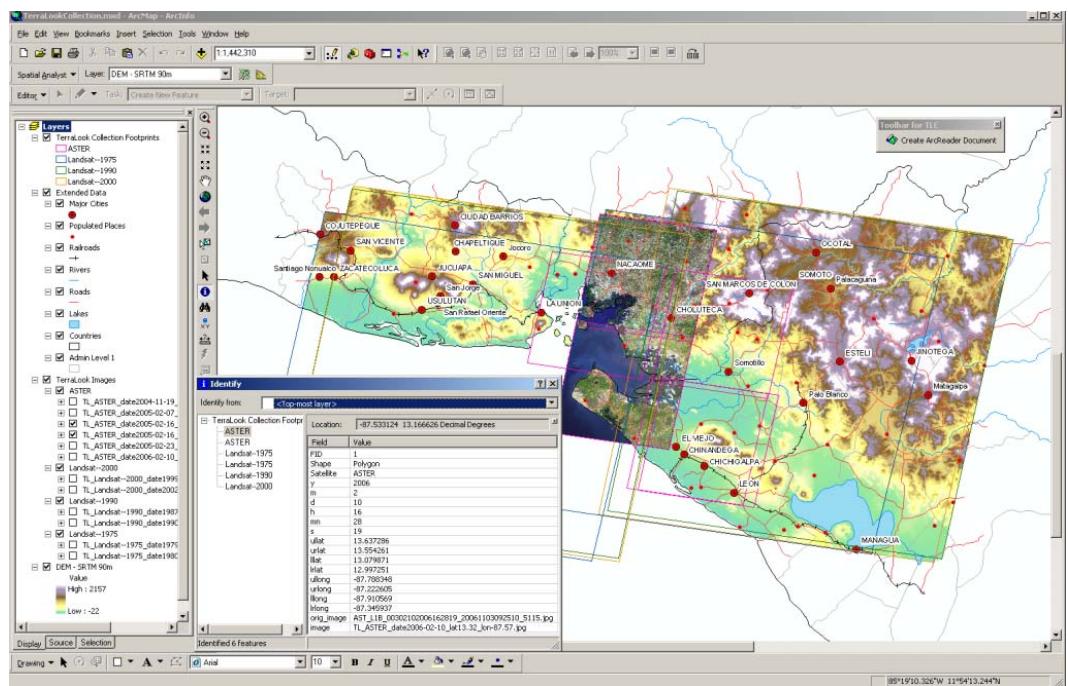


Figure 7. TerraLook Collection in the customized ArcMap document.

The TerraLook footprint and the images' metadata can be displayed from ArcMap or ArcCatalog, allowing users to learn more about the source data, content, and process used to create the images. ArcGIS compatible projection files and metadata files are included in the TerraLook Collection (Figure 8).

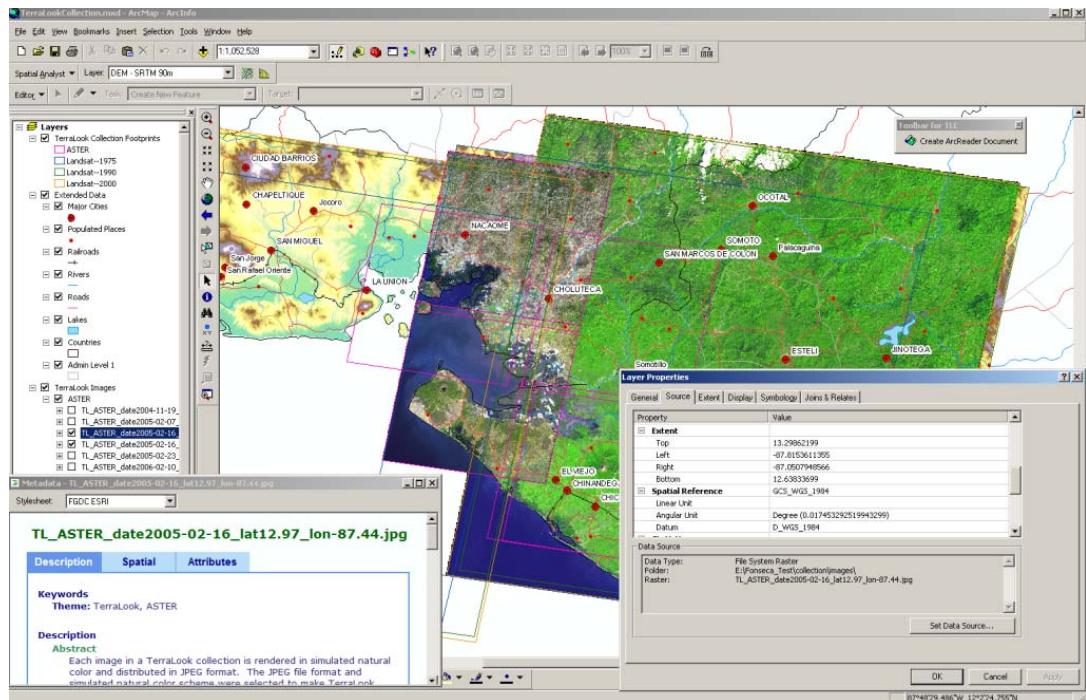


Figure 8. Metadata and spatial reference information available to view in ArcMap.

ArcGIS tools can be used to add local knowledge by either including existing data or by interactive digitizing of features. Ground-sampled information and annotation can be added to the document file to provide a more complete picture of the study area represented in the TerraLook Collection.

A toolbar, provided with the customized ArcMap Document, called “Toolbar for TLC” can be used to create an ArcReader document. ArcGIS users can share the information displayed in the customized ArcMap document using ArcReader with users who do not have ArcGIS desktop software installed. ArcReader is free software available from ESRI that can be used to visualize geographic data. The ArcReader document can be created in the collection folder using the “Toolbar for TLC.” In this way, users can create a zip file, which contains the TerraLook Collection and the ArcReader document (Figure 9).

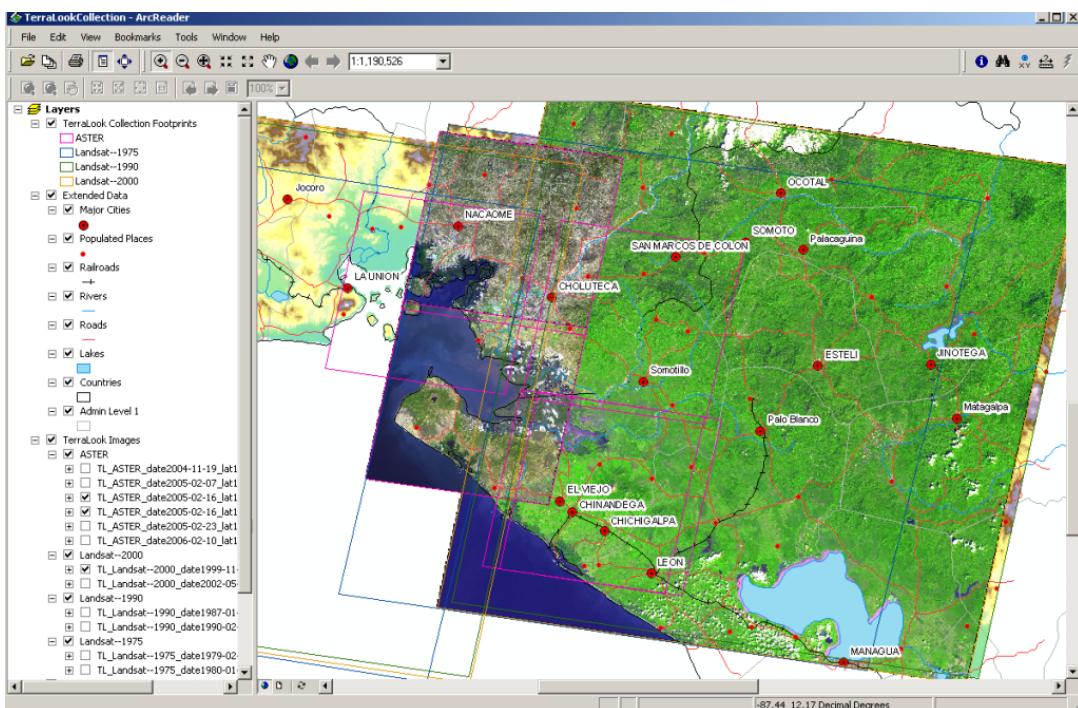


Figure 9. ArcReader document created from the customized ArcMap document.

## ArcGIS Explorer Document for TerraLook Collections

As a complement for visual interpretation and comparison using ArcGIS products and TerraLook Collections, an ArcGIS Explorer document (NMF File) is included in the TerraLook Collections. ArcGIS Explorer is a free application that allows the addition of local data and the use of 2D and 3D Web services available from the ArcGIS Resource Center to create custom maps and perform spatial analysis using local (Creating Notes, Measure, etc.) or custom tasks available from the ArcGIS Resource Center (Wikipedia Search, Weather Finder, Add Photos Task, etc.) (Figure 10).

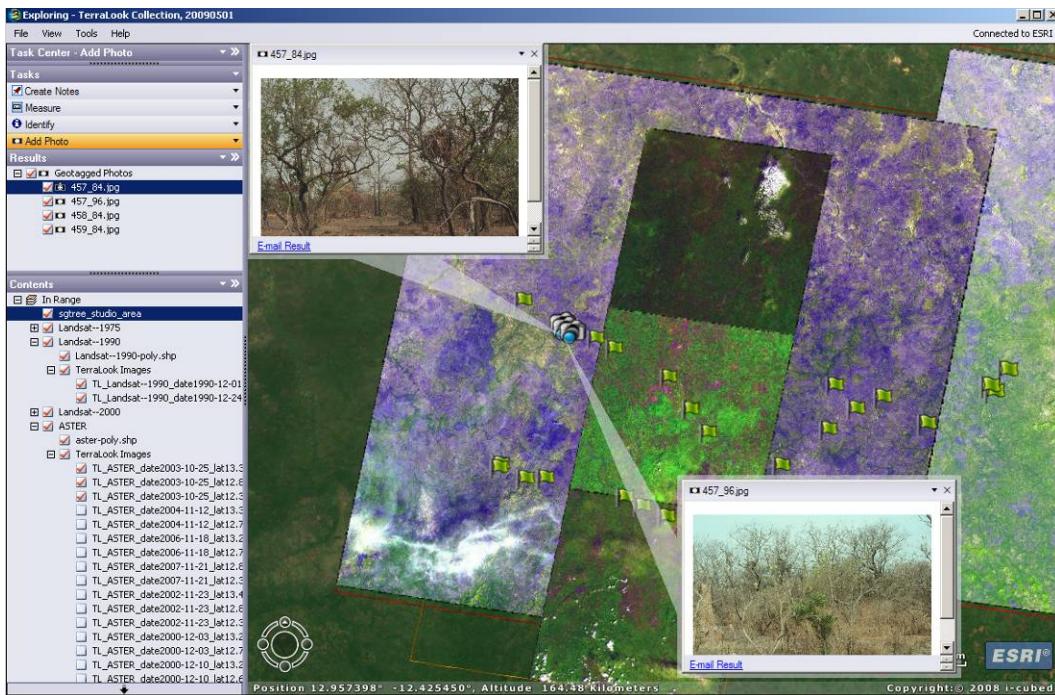


Figure 10. ArcGIS Explorer document displaying a TerraLook Collection with ground photos for two point study sites in Senegal. Flag icons represent ground sample locations and camera icons represent sites with photography.

## Adding Ground photos in ArcGIS Explorer documents

The ArcGIS Resource Center for ArcGIS Explorer allows the addition of user's maps, layers, tasks, and results to ArcGIS Explorer documents. For example, the "Add Photo" task was used to add ground photos to a TerraLook Collection (Figure 10). To add this task to the ArcGIS Explorer document for a TerraLook Collection, it is necessary to go to the Resource Center > ArcGIS Explorer > Tasks and click the link for Add Photo, and an NMF file will be added to the ArcGIS Explorer tool.

The photos to be added in the ArcGIS Explorer documents using the "Add Photo" task must be geo-tagged; that is, they must have latitude and longitude information stored with the photos. If the picture does not contain geo-tags, several geo-tagging tools are available.

Once the geo-tagged photos are ready, click the "Add Photo" task and browse to and select the folder containing the photos, then select the pictures to be added to the ArcGIS Explorer document by clicking the "Place Photos" button (Figure 11). Camera icons will be added to show the location of each photo. To see the picture, click the camera icon and the photo will display in a pop-up window.

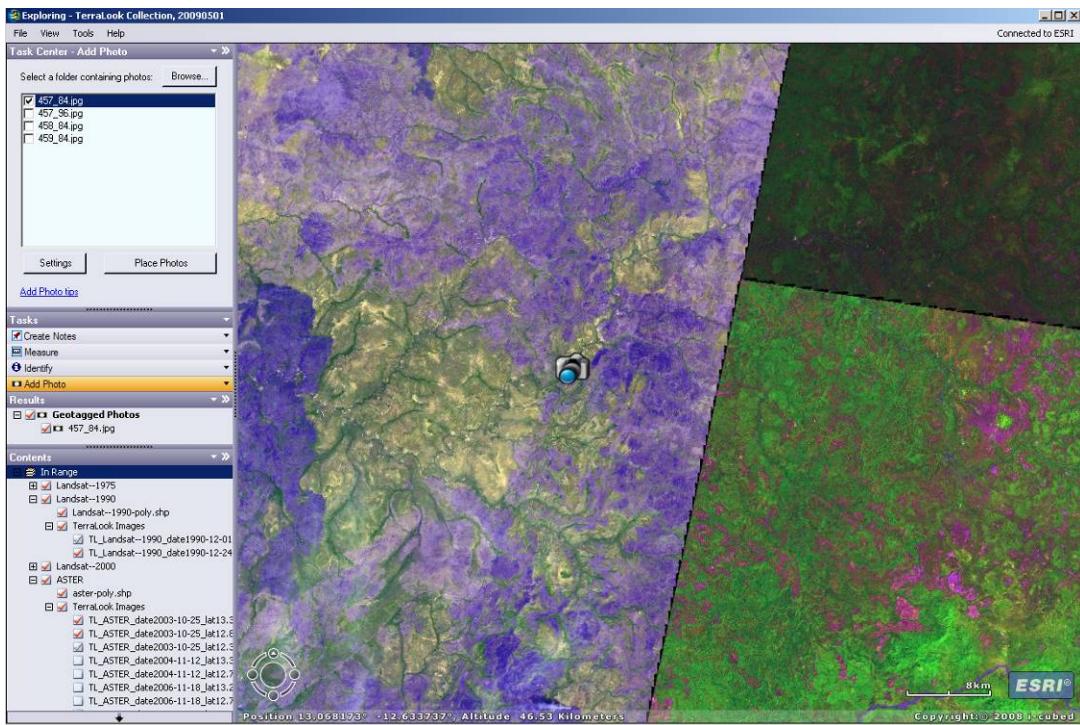


Figure 11. Ground or aerial photographs can be added using the “Add Photos” task in the ArcGIS Explorer document to help document features in the satellite images. The locations of “Placed Photos” are represented by camera icons.

## Conclusions

TerraLook Collections offer easy-to-use methodologies for the analysis and visualization of land resource changes using satellite images in ArcGIS products: images, image footprints, projection files, and metadata. Different ArcGIS solutions were developed to use with TerraLook Collections. A customized ArcMap document bundled with the TerraLook Collections allows users to open a TerraLook Collection with a defined structure and symbology. A Python script is used as a tool in ArcToolbox to create extended data (vector type for reference data and raster data for DEM) for a TerraLook Collection, and this data can be displayed by the customized ArcMap document. Users can share their TerraLook Collections with users who do not have ArcGIS software by publishing with the ArcGIS Publisher extension interactive maps for use in the free ArcReader application using a tool provided in the customized ArcMap document.

The TerraLook Collection provides a valuable and easy-to-use foundation of remotely sensed data for monitoring environmental change. The ability to create extended collections permits the addition of reference data to create a more complete baseline database. Furthermore, ArcGIS tools can be used to add local knowledge to the TerraLook Collection through the addition of existing local datasets, interpreted data, annotation describing features, and photography. These augmented TerraLook Collections can easily be shared with others.

## Acknowledgements

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The TerraLook product and software build on the success of the NASA Jet Propulsion Laboratory's Protected Area Archive project. TerraLook has received support from The Nature Conservancy, the World Bank Development Grant Facility Program's Inter-American Biodiversity Information Network Connectivity Project, the U.S. State Department, the Gordon and Betty Moore Foundation's Amazon Protected Area Network project, and The World Conservation Union. The TerraLook project is a joint project between the USGS EROS Center and NASA Jet Propulsion Laboratory.

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- ASTER Web site: <http://asterweb.jpl.nasa.gov/>
- USGS EROS Center Web site: <http://eros.usgs.gov>
- Global Land Survey: [http://landsat.usgs.gov/science\\_GLS2005.php](http://landsat.usgs.gov/science_GLS2005.php)
- gData from University of Berkeley, GIS Data by countries:  
<http://biogeo.berkeley.edu/bgm/gdata.php>
- Geo Data Portal – The Environmental Database – UNEP: <http://geodata.grid.unep.ch/>
- CGIAR-CSI SRTM 90-m DEM Digital Elevation Database: <http://srtm.cgiar.org/>
- ArcGIS Explorer: <http://www.esri.com/software/arcgis/explorer/index.html>
- ArcGIS Explorer Resource Center: <http://resources.esri.com/arcgisexplorer/>
- ArcScripts Home: <http://arcscripts.esri.com/>

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