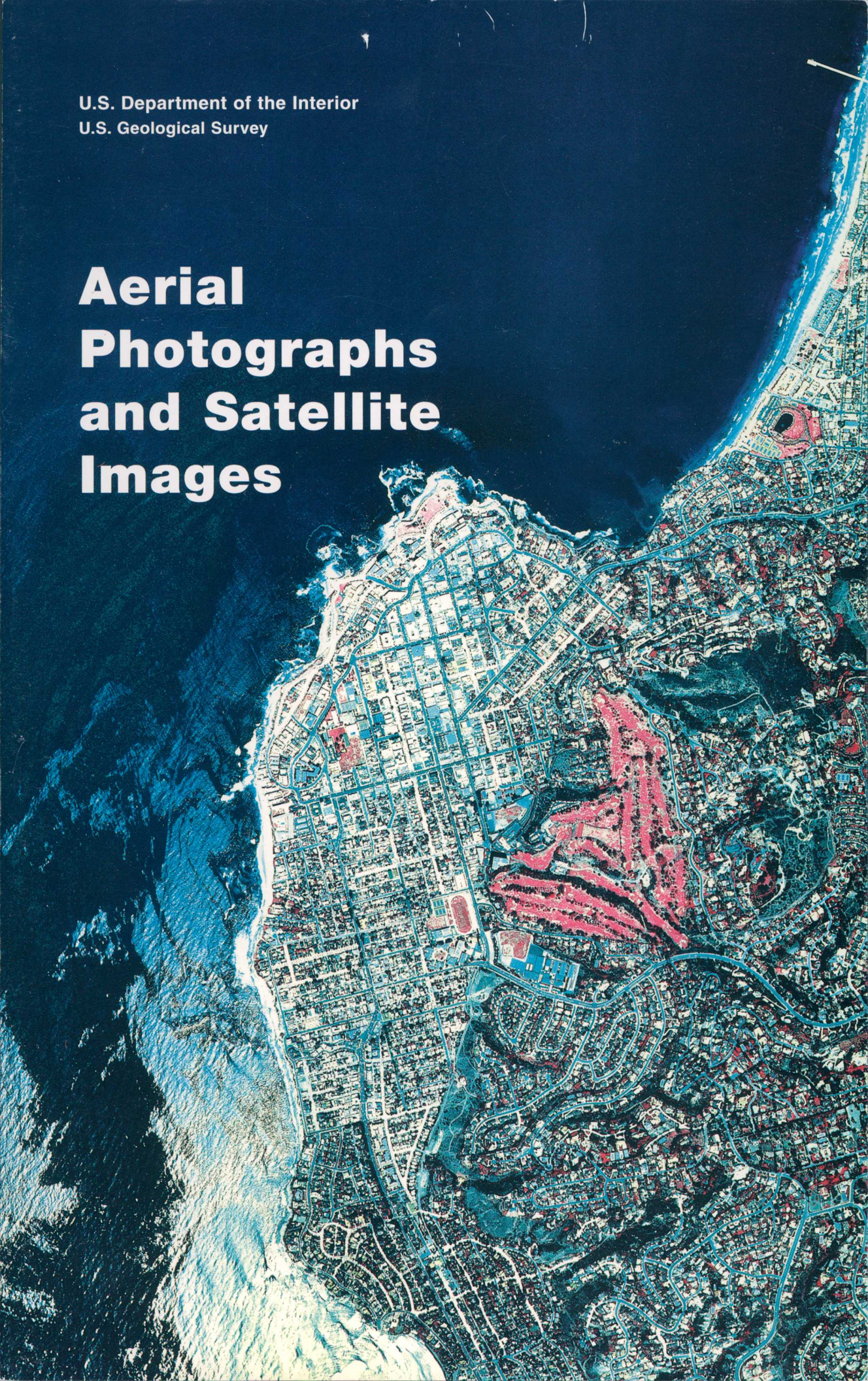
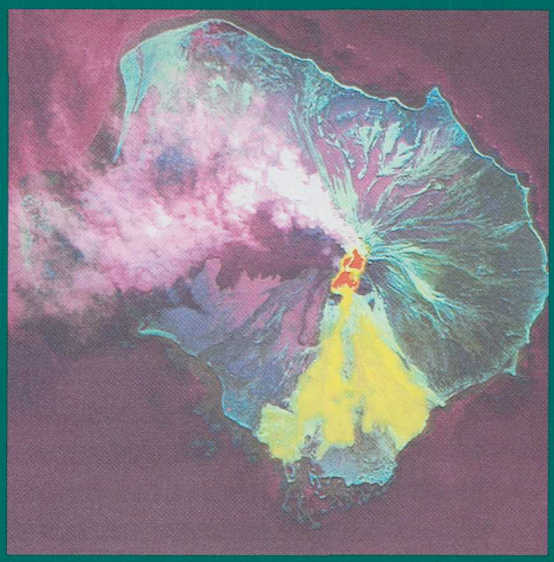
U.S. Department of the Interior
U.S. Geological Survey

Aerial Photographs and Satellite Images



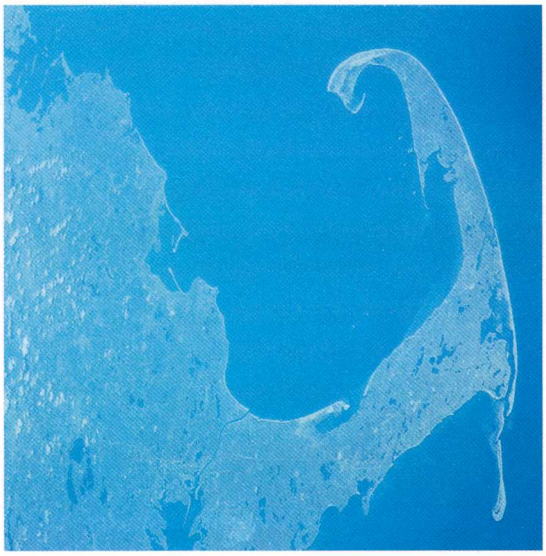


E-1708-99CT

Augustine Volcano, Alaska, Landsat 5 TM, April 1986. (Reduced to 75 percent)

Cover: La Jolla, Calif., NAPP color infrared, original scale:1:40,000, September 1990.
NAPP Roll 1854, Frame 40

Unless otherwise noted, all images in this booklet have been reduced 50 percent.



E-1337-99CT

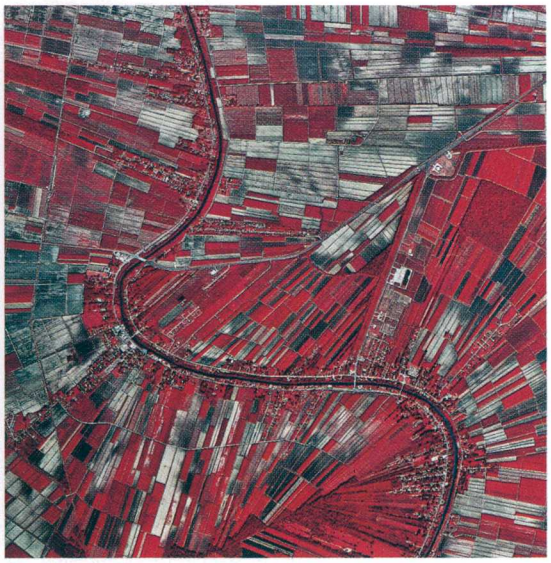
Cape Cod, Mass., space shuttle photograph, April 1981.

NHAP 84 Roll 305, Frame 32

San Diego, Calif., NHAP color infrared, original scale: 1:58,000, February 1985.

Aerial Photographs and Satellite Images

Photographs and other images of the Earth taken from the air or from space afford valuable information about the planet; its landforms, vegetation, and resources. Aerial and satellite images permit researchers to see and accurately map patterns of land use that otherwise are not readily visible from the ground. Transient phenomena such as ocean currents or pollution discharges can be studied. The aerial perspective allows us to see landscape features on regional, continental, or even global scale.



NAPP Roll 1423, Frame 96

Bayou Laforche, La., NAPP, color infrared, original scale: 1:40,000, October 1990.

E-1815-99CT

Horseshoe Falls (Niagara Falls), N.Y. and Canada, looking South, low oblique (scale will vary), EPA, July 1989.

The U.S. Geological Survey and Remote Sensing

Because photographs and images taken from the air or from space are acquired without direct contact with the ground, they are referred to as remotely sensed images. The U.S. Geological Survey (USGS) has used remote sensing from the early years of the 20th century to support earth science studies and for mapping purposes.

The USGS began using aerial photographs for mapping in the 1930's. Successive aerial photographs can be overlapped, and using a stereoscope, can be made into contour maps. Although aerial photographs from earlier decades are scarce, the USGS archives photographs from its mapping projects and from national programs.

Photographs and some images from U.S. space programs such as the Landsat program, begun in 1972, are also held by the USGS. Most Landsat scenes can only be obtained in digital form for use in computer-based image processing and geographic information systems or as film positives or negatives.

This booklet discusses some characteristics of aerial photographs and satellite images and the types of images that are available from the USGS.

Background: Pierre, S. Dak., Landsat 2 MSS, May 1976. (Enlarged 200 percent)
E-1833-99CT

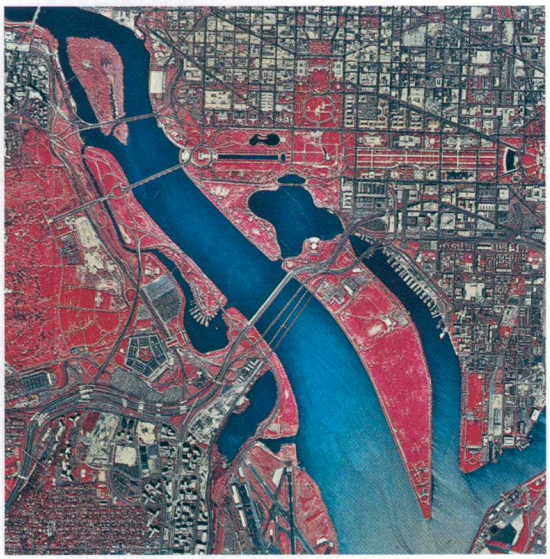
How Images Are Classified

Images taken from above the Earth are usually categorized according to the altitude of the aircraft or spacecraft, the type of image medium, and the type and characteristics of the sensor.

Altitude

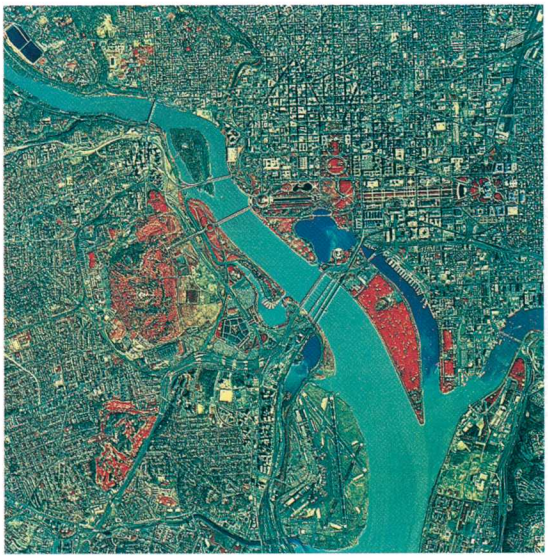
Manned or unmanned spacecraft usually collect images from altitudes greater than 150 miles. Aircraft commonly operate at altitudes from 5,000 to 60,000 feet. The height from which a photograph or image is taken and the physical characteristics of the sensor, including the focal length, largely determine the area covered and the amount of detail shown in a remotely sensed image. In general, the level of detail is the greatest in low-altitude photographs that cover relatively small areas. Satellite images cover larger areas but show less detail.

Views of the same area from progressively higher altitudes



NAPP Roll 4, Frame 78

Medium altitude aerial photograph of Washington, D.C., NAPP, color infrared, original scale: 1:40,000, April 1988.



NHAP 80 Roll 581, Roll 27

High altitude aerial photograph of Washington, D.C., NHAP, color infrared, original scale: 1:58,000, March 1982.

E-1488-99CT

Washington, D.C. and vicinity, Landsat 5 TM, January 1984.

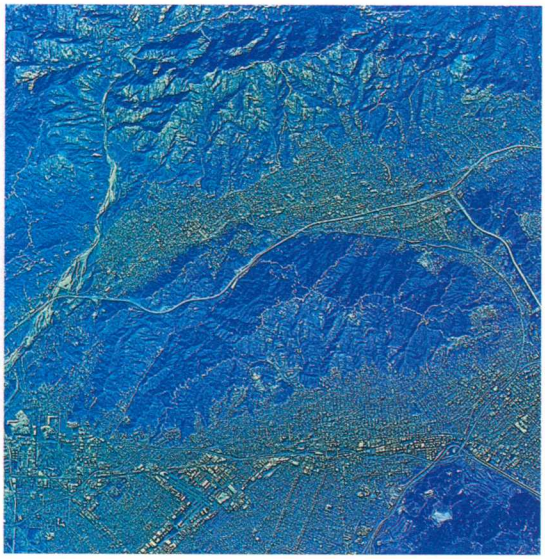
LM85205115114X0

Washington, D.C. and vicinity, Landsat MSS, October 1989.

Comparison of four types of image media of the same area

NAPPB Roll 1840, Frame 170

Los Angeles, Calif., NAPP, black and white, original scale: 1:40,000, August 1989.

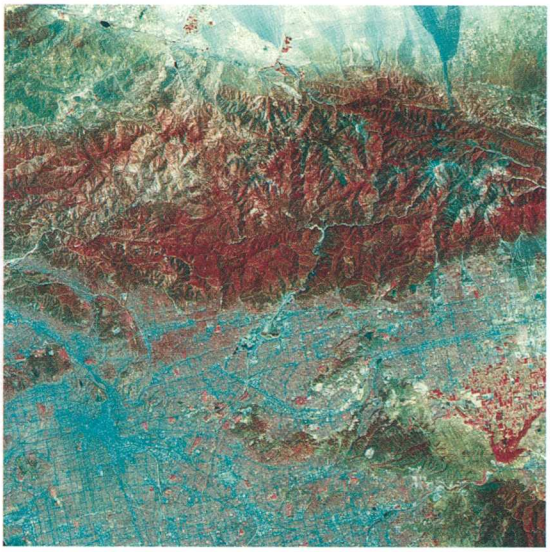


AB55800369 ROLL Frame 1265

Los Angeles, NASA Ames U-2, natural color, scale: 1:128,000, January 1988.

NAPP Roll 1840, Frame 170

Los Angeles, NAPP, color infrared, original scale: 1:40,000, August 1989.



E-1702-99CT

Los Angeles, Landsat TM, November 1987.

Image media

Aerial photographs are produced by exposing film, an image medium, directly to solar energy reflected from the Earth. Photographic film has been used for aerial reconnaissance, for both military and civilian purposes, since the middle of the 1860's. Black-and-white film was used at first; color film became widely used in the 1950's.

Color-infrared film, which records energy from portions of the electromagnetic spectrum invisible to the human eye, was developed to detect camouflaged military installations in the 1940's. In a color-infrared (also known as a false-color) photograph, near-infrared light reflected from the scene will show as red, red will show as green, green as blue, and blue as black. Color-infrared film is useful for distinguishing between healthy and diseased vegetation, for delineating bodies of water, and for penetrating atmospheric haze.

Black-and-white and color-infrared films are used today in both high- and low-altitude aerial photography. Natural-color film is used more rarely.

Sensors

Cameras of various types are used to take aerial photographs. Cameras can be carried on aircraft or on such spacecraft as the space shuttle. Satellites commonly use electronic scanners to record ground scenes in digital, or computer-readable, form. Aircraft can also carry electronic scanners. Sensors can be passive; that is, recording radiation reflected from the Earth, or active, generating their own energy. A camera is passive; so are the sensors used aboard the Landsat satellites. These sensors record reflected energy in the visible, infrared, and thermal portions of the spectrum. Satellite data are displayed as images whose colors resemble color-infrared aerial photographs, but the colors of a given image can be manipulated by computer to enhance landscape features.

Side-looking airborne radar (SLAR) instruments on aircraft or satellites generate their own energy and record the amount of energy reflected back to them from the ground.

Original scale

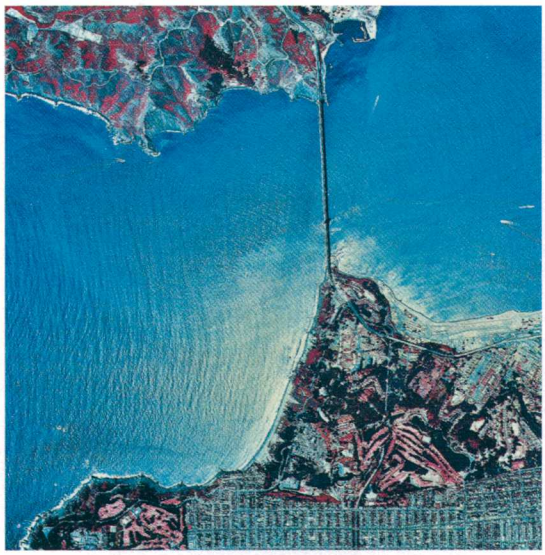
2x enlargement

Overall size

These images represent the three standard paper print sizes for aerial photographs available from the USGS. The standard contact print size is 9 by 9 inches. Enlargements to 18 by 18 inches (2x), and 36 by 36 inches (4x) can also be ordered. In this scene of Washington, D.C., the 9-inch contact print (upper left) represents the original scale of 1:40,000, where 1 inch on the image represents approximately 3,333 feet on the ground. The 18-inch print (above) represents a 2x enlargement with a scale of 1:20,000, where 1 inch on the image represents approximately 1,666 feet on the ground. The 36-inch print (right) represents a 4x enlargement with a scale of 1:10,000, where 1 inch on the image represents approximately 833 feet.

NAPP Roll 4, Frame 78

4x enlargement



NAPP Roll 511, Frame 159

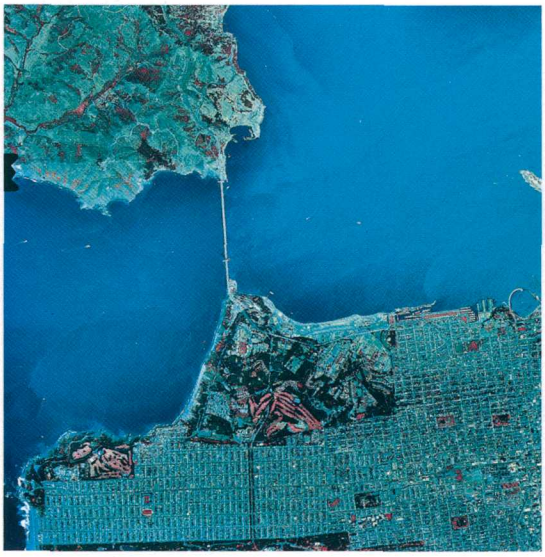
Golden Gate Bridge, San Francisco, Calif., NAPP color infrared, original scale: 1:40,000, June 1987.

NAPPW Roll 6365, Frame 36

Golden Gate Bridge, NAPP black and white, original scale: 1:40,000, August 1993.

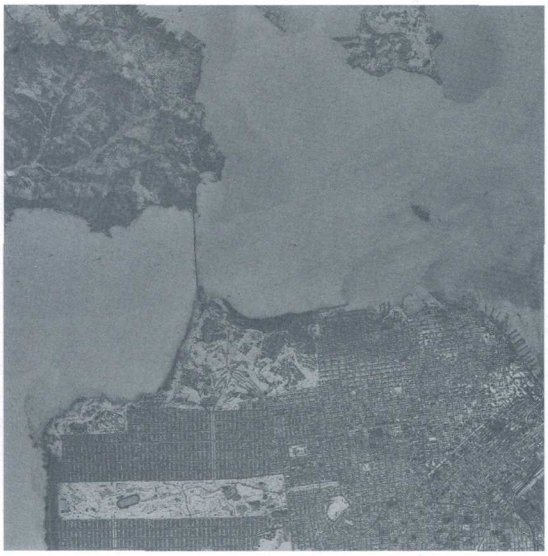
Aerial Photographs

Various types of aerial photographs are archived by the USGS. Although the USGS has used aerial photographs for many decades, the availability of photographs from the earliest years is limited. Most recent photographs are from national programs and were taken at relatively high altitudes with predominately black-and-white or color-infrared film.



NHAP 82 Roll 261, Frame 130

Golden Gate Bridge, NHAP color infrared, original scale: 1:58,000, August 1982.



NHAP 82 Roll 252, Frame 58

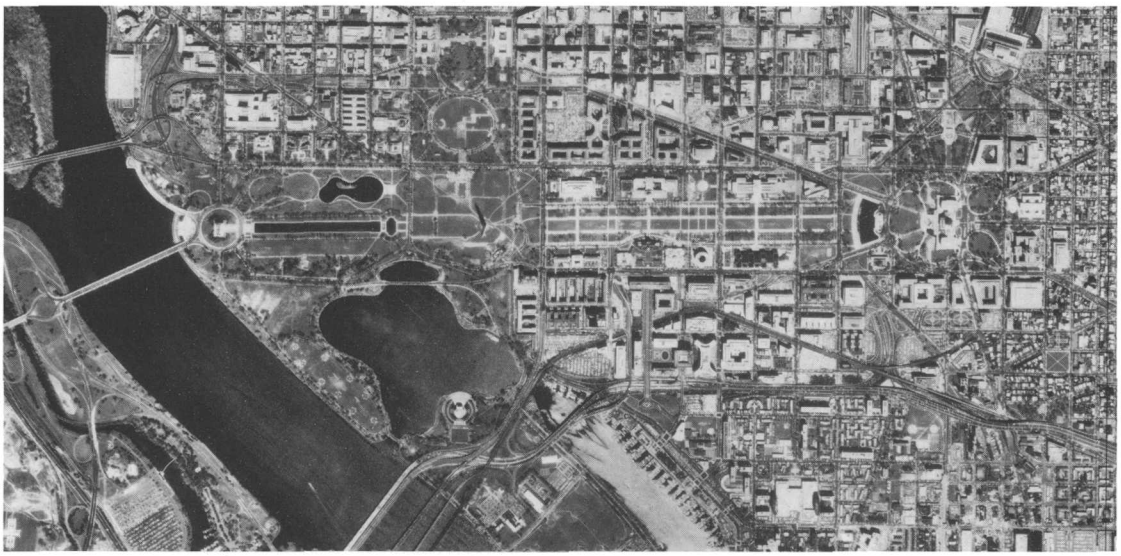
Golden Gate Bridge, NHAP black and white, original scale: 1:80,000, August 1982.

National Aerial Photography Program

The National Aerial Photography Program (NAPP) was established in 1987 to coordinate the acquisition of aerial photographs for the United States among Federal and State agencies. NAPP photographs are used for mapping, resource planning, land management, and agricultural monitoring. Taken from aircraft flying nominally at 20,000 feet above the terrain, each NAPP photograph covers about 32 square miles of ground. Black-and-white and color-infrared photographs are available from the NAPP program.

National High Altitude Photography Program

The National High Altitude Photography Program (NHAP) was a Federal project that preceded NAPP, running from 1978 to 1988. NHAP photographs were taken simultaneously with two cameras, one containing black-and-white film, the other color infrared. The NHAP aircraft flew at 40,000 feet above the terrain. These photographs cover more area, but show less detail, than NAPP photographs. An NHAP black-and-white photograph covers about 129 square miles, and because of the longer focal length in the second camera, an NHAP color-infrared photograph covers about 68 square miles.



Washington, D.C., section of a 1-m resolution, quarter-quadrangle digital orthophoto, date of photography-April 1988. (Reduced 30 percent)

Orthophotos and digital orthophotos

Orthophotos are prepared from perspective aerial photographs or digital representations of these photographs in which the displacements caused by differences in terrain elevations and camera tilt have been removed, giving the orthophoto the geometric characteristics of a map. That is, measurements of distances between points on an orthorectified aerial photograph can be made accurately because of the common scale of the new image. Because aerial photographs show the entire texture of the ground in much greater detail than do conventional line maps, orthophotos are useful for updating maps and in land studies. The USGS produces digital versions of orthophotos for map revision and for computer analysis using geographic information systems.

Aerial photographs from mapping programs

The USGS archives photographs used for making maps that are not associated with national programs. The mapping photographs of some other Federal agencies are also available. Some of these photographs date back to the 1950's. Most show more detail than NAPP and NHAP photographs. These mapping photographs may be in black and white or, in a few cases, in natural color.

Aerial photographs from the National Aeronautics and Space Administration (NASA)

NASA uses aerial photographs for research and to test remote sensing techniques and instruments. These photographs are available in various formats and were taken from altitudes of a few thousand feet up to 60,000 feet, although the majority were collected at the higher altitude. NASA aerial photographs are available in black and white, natural color, or color infrared, but only for certain areas. Digital multispectral scanner data are also available.

Manned spacecraft photographs

Photographs were acquired over limited areas of the Earth on NASA's Gemini (1965-66) and Apollo (1968-1969) missions. Three Skylab missions in 1973 and 1974 provided more than 35,000 photographs.

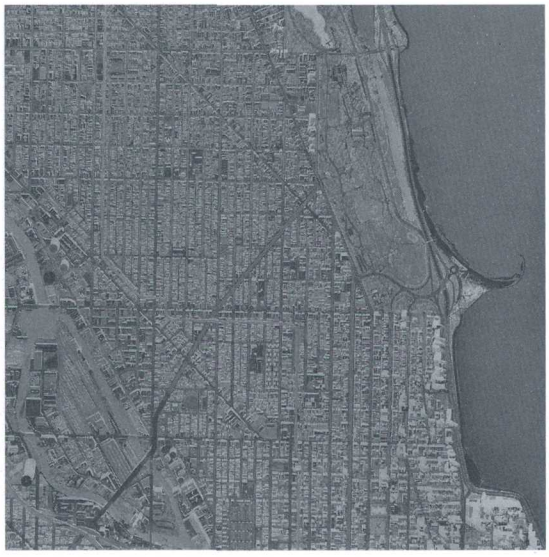
Astronauts aboard the space shuttle, which began flying in 1981, have taken many photographs of the Earth with hand-held cameras. The photographs from these missions document sites of scientific interest around the world and depict temporary phenomena such as hurricanes and erupting volcanoes. Most of these photographs are in natural color.

Aerial photographs from Government agencies

The Earth Resources Observation Systems (EROS) Data Center of the USGS stores negatives of aerial photographs from other Federal agencies, including the Bureau of Land Management, the Bureau of Reclamation, the Bureau of Indian Affairs, NASA, and the former Departments of the Army, Navy, and Air Force. Copies of these photographs can be ordered directly from the USGS's Earth Science Information Centers.

Major metropolitan areas of the United States

Color-infrared aerial photographs of the central business districts of more than 100 cities in the United States are available. The photographs are selected largely from the NHAP program, prior to 1987, and were chosen for their high quality. Most of these photographs were taken with color-infrared film at a scale of 1:58,000 (1 inch equals about 0.9 miles or 1 centimeter equals about 0.6 kilometers).

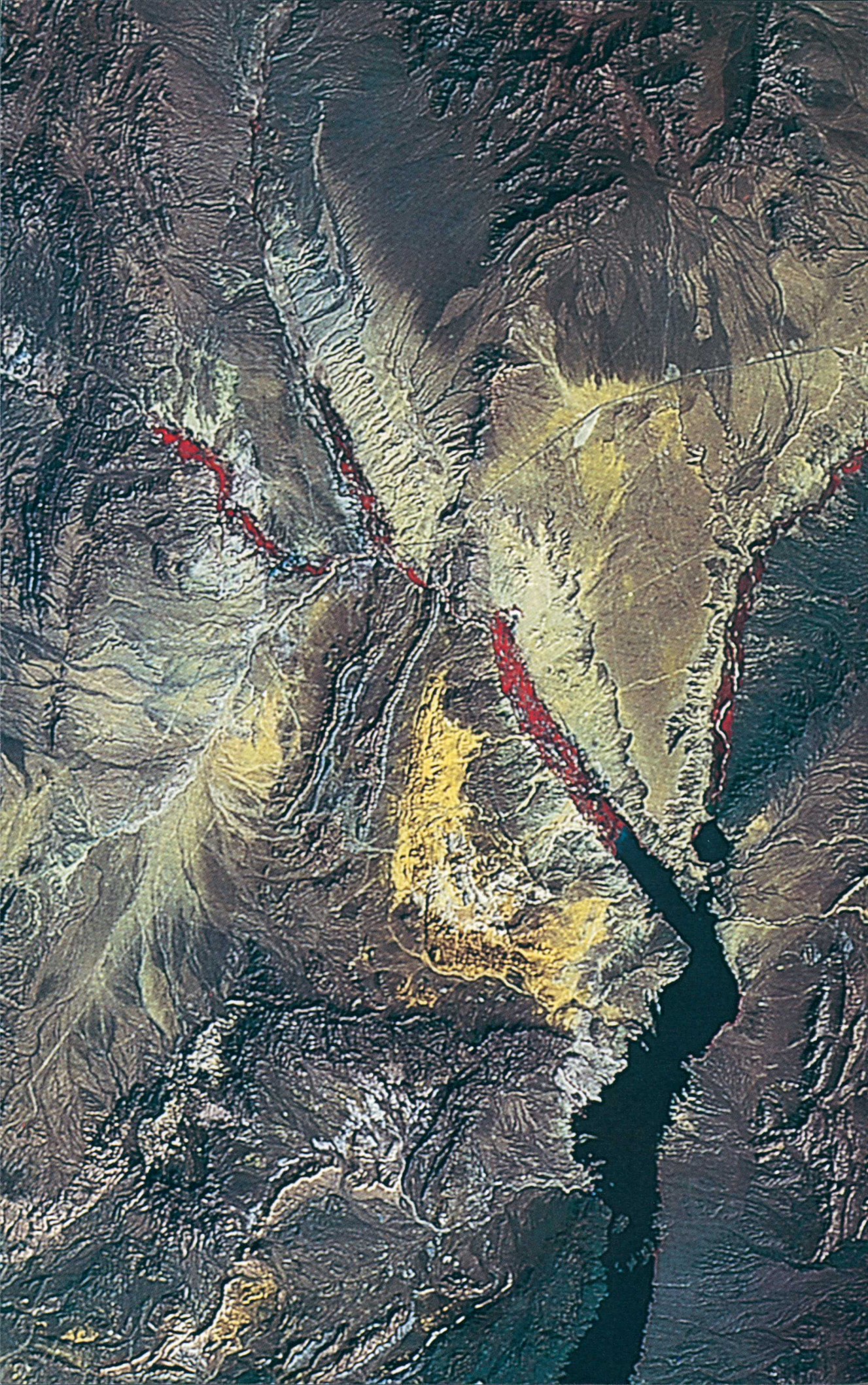


GS-SA Roll 4, Frame 40

Chicago, Ill. and Lake Michigan shoreline, USGS project, black and white, original scale: 1:23,600, March 1952.

E-1804-99CT

Hurricane Elena, space shuttle photograph over the Gulf of Mexico, September 1985.



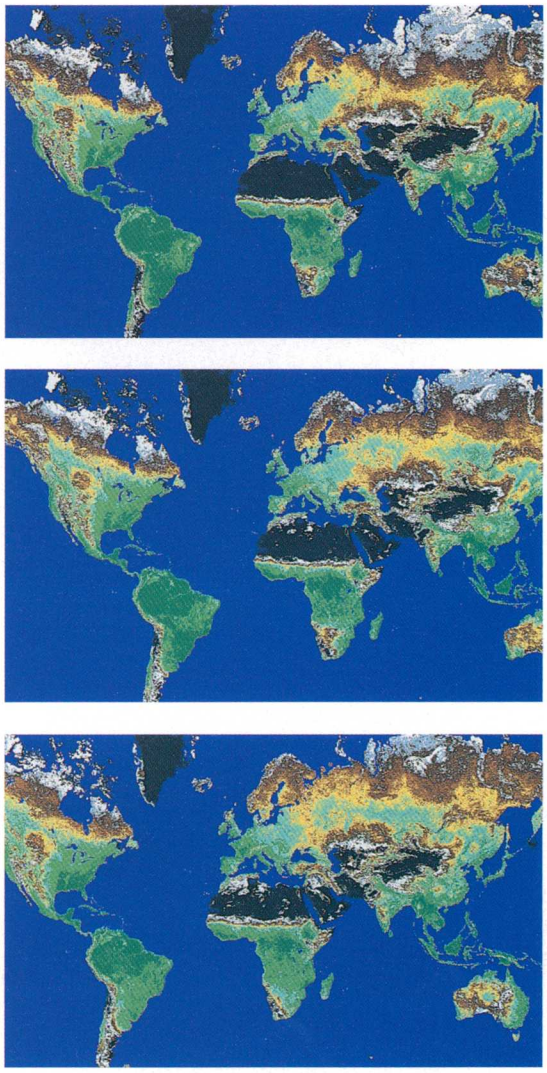
Satellite Images

The EROS Data Center processes and stores satellite data from several different types of satellites. The major types are described below.

The Landsat Program

In 1972, the United States launched its first Earth Resources Technology Satellite, ERTS-1, later renamed Landsat 1, for experimental global coverage of the Earth's land masses. Landsats, serially numbered, were launched in 1972, 1975, 1978, 1982, and 1984.

Data are collected by sensors that measure a range of wavelengths of electromagnetic energy reflected or emitted from the Earth. The broad wavelength bands are often from those parts of the electromagnetic spectrum outside the range of human eyesight, showing normally invisible land characteristics. The Landsat data are transmitted to Earth where they are processed by computers and archived.



E-1884-99CT

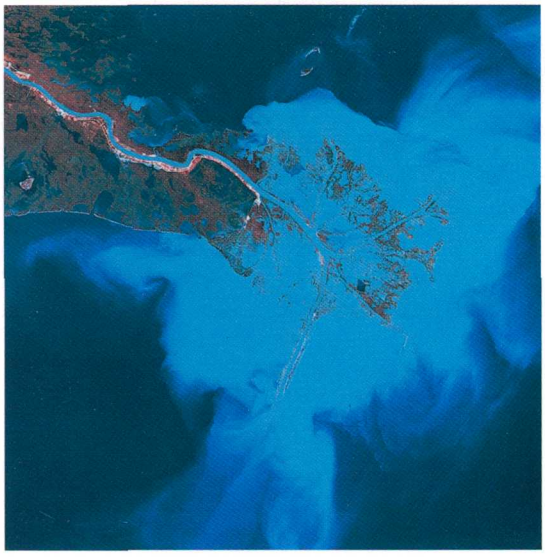
Global summation of vegetation greenness index for calendar years 1986-1988 (black = low greenness, dark green = high greenness), from AVHRR data, source - NOAA.
(Reduced to 87 percent)

Background: Las Vegas, Nev., Landsat 4 TM, April 1983. (Enlarged 420 percent)
E-1469-99CT

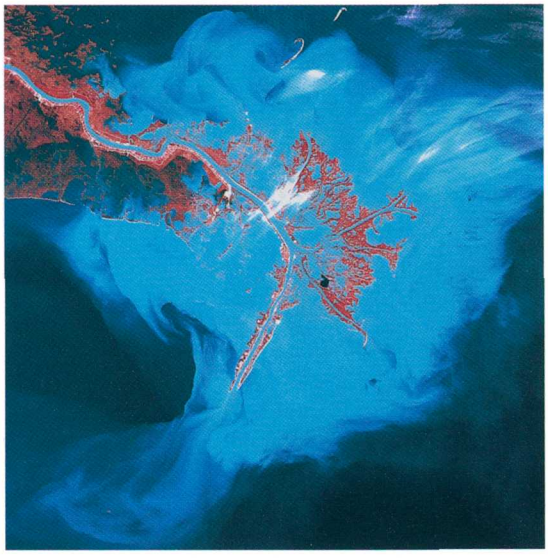
Landsats 1-5 have carried versions of a sensor called the multispectral scanner (MSS), which collects data simultaneously from four broad bands of the electromagnetic spectrum, from visible green through near-infrared wavelengths. The MSS images in this booklet have a picture element (pixel) resolution of 79 meters–that is, the height and width of each pixel correspond to 79 meters or about 259 feet on the ground. Landsats 1 and 2 also carried a sensor called the return beam videcon, or RBV, with high geometric accuracy but lower spectral detail than the MSS. Because of technical problems, RBV operations were limited and the sensors were not used on later spacecraft.

The thematic mapper (TM) sensor carried on Landsats 4 and 5, in addition to the MSS, gives higher resolution than the MSS, each pixel corresponding to 30 meters, or about 98 feet on the ground. The TM sensor also records a greater number of bands than the MSS, yielding more detailed spectral information. Landsat images can be processed to emphasize different features of the land, making such data especially useful for scientific studies.

Landsats 4 and 5 pass from north to south over the Equator at an altitude of 705 kilometers (438 miles) each day at about 10 a.m., and their orbits provide repeat coverage of the Earth, allowing the detection of changes. Cloud cover and the need to transmit data directly to a ground station affect the amount of acceptable continuous repeat coverage.

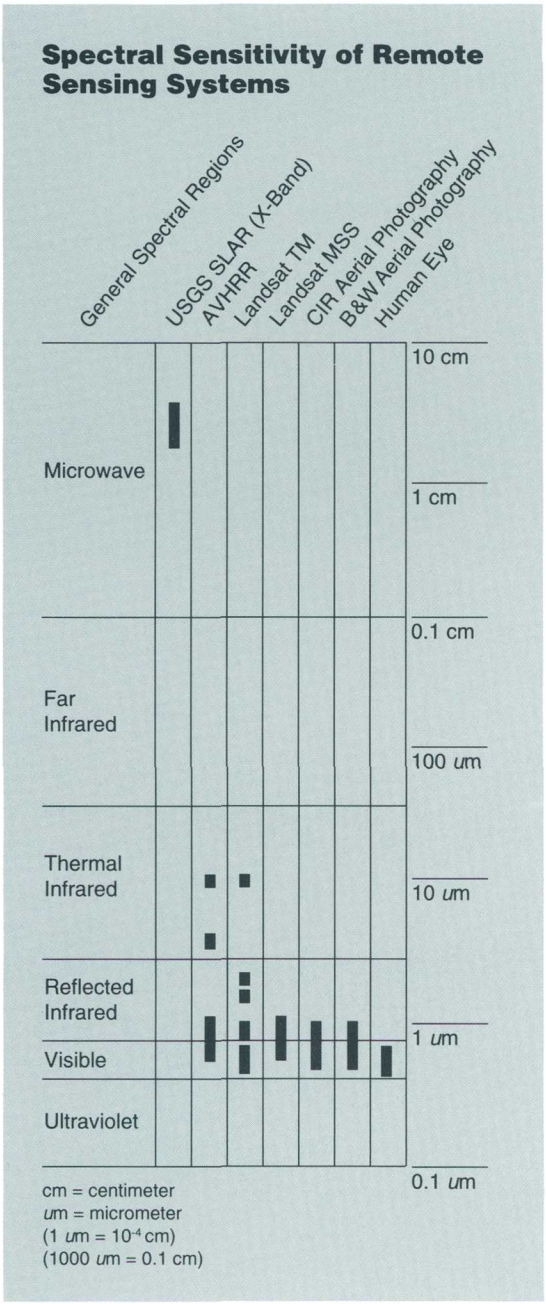


E-1856-810CT



E-1856-810CT

Comparison of Landsat MSS scenes of the Mississippi River Delta, January 16, 1973, and March 3, 1989. (Reduced to 68 percent)



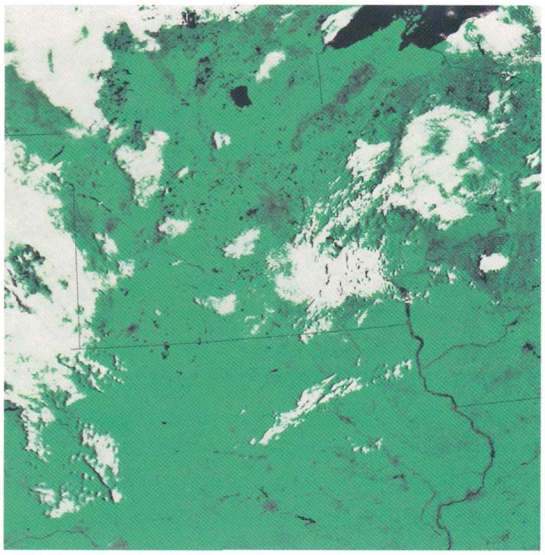
E-1879-88CT

Greenness map, AVHRR, August 11–20, 1990.

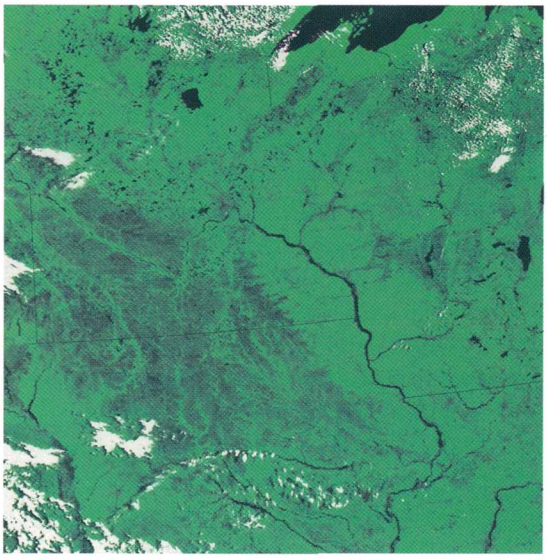
Advanced very high resolution radiometer

The advanced very high resolution radiometer (AVHRR) is one of several sensors aboard meteorological satellites operated by the National Oceanic and Atmospheric Administration. AVHRR data are collected in the visible, near-infrared, and thermal-infrared portions of the electromagnetic spectrum at a resolution of 1.1 kilometer (about 0.68 of a mile). Two satellites each make about 14 passes over the Earth in a 24-hour period, one in the morning and one in the afternoon. Thus, data are collected more frequently than Landsat data, but with much coarser resolution and for much larger areas.

The EROS Data Center has been receiving and processing 1-kilometer resolution data from the AVHRR system since 1987 and using them for a variety of land applications, such as drought monitoring, fire fuel assessment, and land surface characterization. The use of these data for management purposes complements the traditional use of 4- and 16-kilometer resolution AVHRR data for meteorological applications. Some AVHRR data are available on CD-ROM.

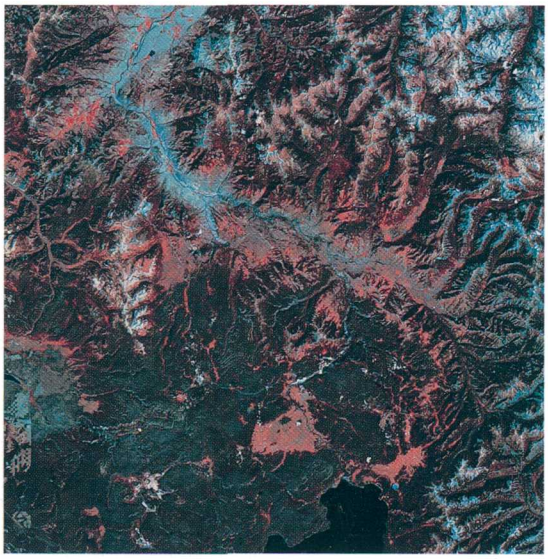


E-1911-99CT

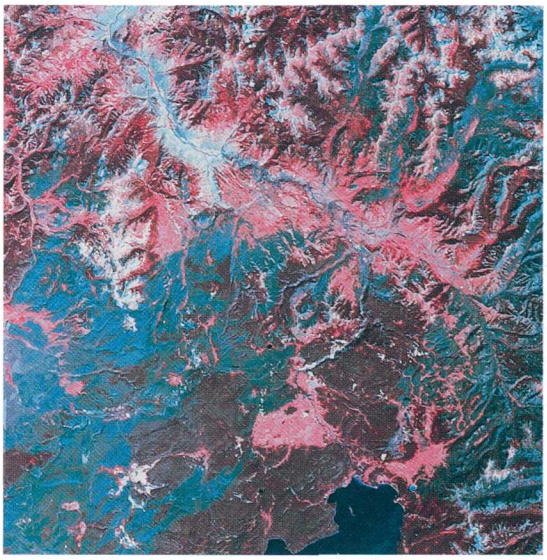


E-1917-99CT

Effects of flooding on the Mississippi River Basin, AVHRR, July 17, 1992, and July 12, 1993.



E-1853-810CT



E-1853-810CT

Comparison of Landsat sensors: Yellowstone National Park, Wyo., Landsat MSS, August 1972, and Landsat TM, August 1989. (Reduced to 68 percent)

SI1SSPA00820805

Los Angeles, Calif., SLAR mosaic compiled in April 1986 from radar strips flown in November 1985. (Reduced to 25 percent)

Side-looking airborne radar

Because SLAR systems provide their own energy to illuminate the ground, these images can be collected regardless of the weather or time of day, making such data valuable for mapping parts of the world that are perpetually cloud covered, such as the Amazon Basin. SLAR systems transmit microwave energy to the ground from aircraft. The signal strikes the ground and is reflected and scattered. The portion of the signal that returns to the sensor is recorded as digital values that can be represented on photographic film. The side-looking geometry of the system produces shadows of varying lengths depending on the angle of illumination and the surface relief. Although these shadows enhance subtle terrain features, such as faults and folds, they also obscure land surface detail in the shadow area. SLAR images are useful to scientists studying geologic structures. SLAR images most often consist of image strips and 1:250,000-scale mosaics prepared from these strips. Some SLAR data are available on CD-ROM.

E-1373-99CT

Earthrise from Moon, Apollo 11, July 1969.
(Reduced to 40 percent)

E-1721-99CT

Florida, Landsat 5 TM mosaic, April 1979
and May 1985. (Reduced to 43 percent)

Display Images

The USGS has available aerial photographs and images suitable for framing that can be ordered without custom research. In this category are satellite images and aircraft photographs of selected States, cities, regions, and features within the United States; and of such natural phenomena as fires and volcanic eruptions. Some areas outside the United States are also covered. Some photographs taken on space missions by NASA astronauts are also available in this format.

Ordering Information

USGS aerial photographs covering the United States and worldwide satellite data from the early 1970's to the present can be ordered directly from the USGS. The USGS also has information about images available from other Government agencies and commercial sources. Indexes of aerial photographs and online information about satellite data are also available. For more information or to order any of the products in this booklet, call 1-800-USA-MAPS.

Boston, Mass. metropolitan area, NHAP color infrared, original scale: 1:58,000, April 1985.
(Enlarged 130 percent)
NHAP 85 Roll 53, Frame 236