National Aeronautics and Space Administration

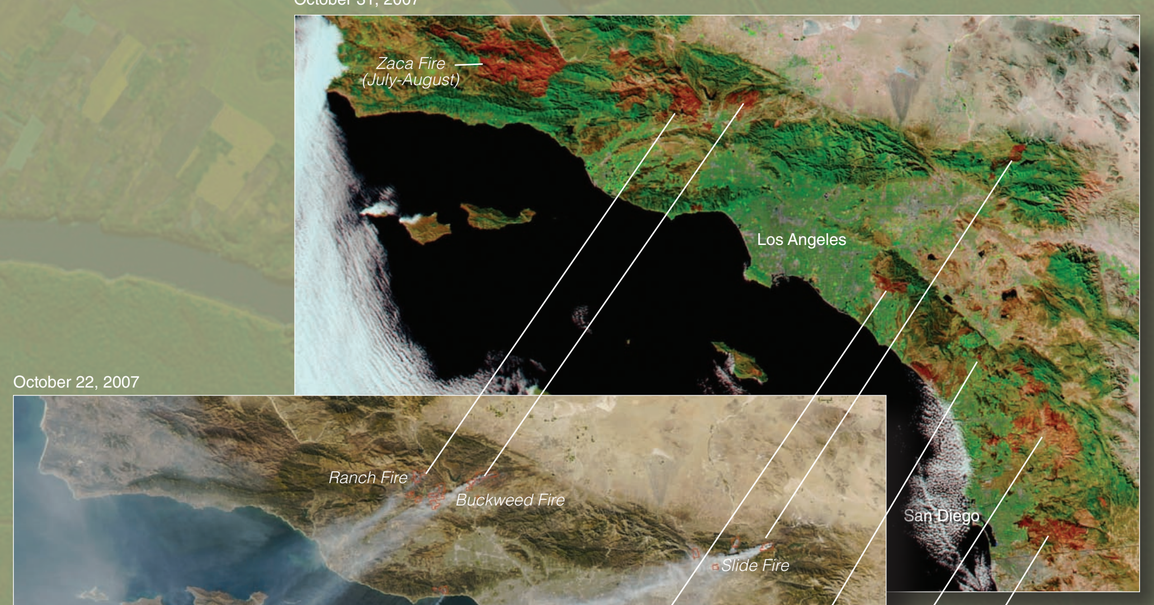
Land

Our Changing Earth

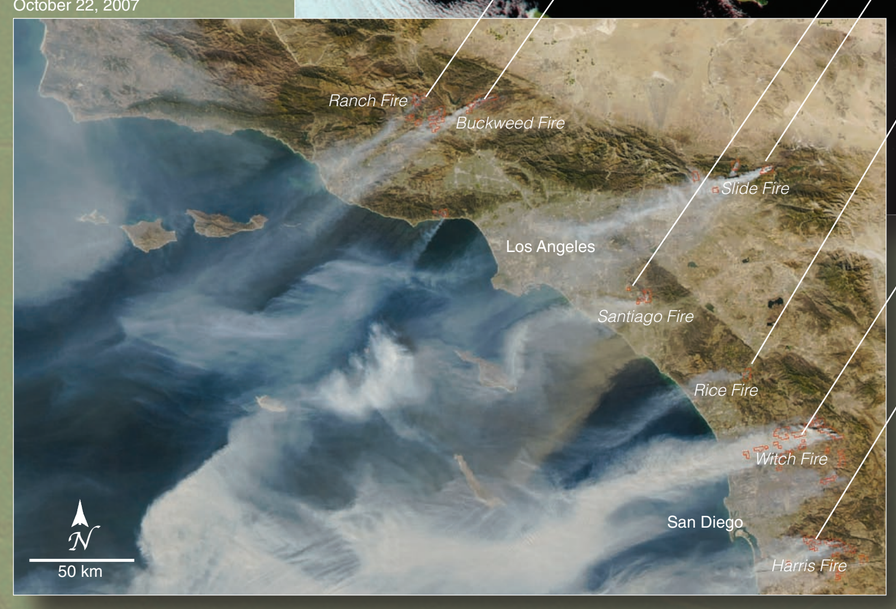
Land ecosystems cover nearly 30% of the Earth's surface. The land surface changes over days, seasons, decades, and longer. Vegetation boundaries shift, cities grow, rain forests and farm lands shrink, amounts of trace chemicals in the air increase and decrease, rivers flood, forests burn, and volcanoes erupt. Activities of the growing human population cause or influence many of these changes.

Space provides an excellent vantage point from which to observe and record land surface changes, especially at a global scale. NASA has embarked on an ambitious effort to measure the effects of changes on our planet and to understand the roles that human activities play in them. A suite of Earth-observing satellites measures different aspects of the land and builds a global picture of change, one location at a time.

October 31, 2007



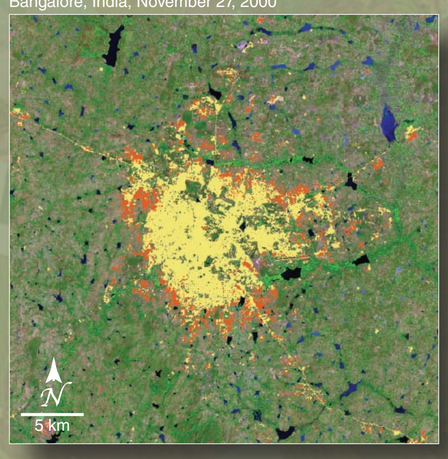
October 22, 2007



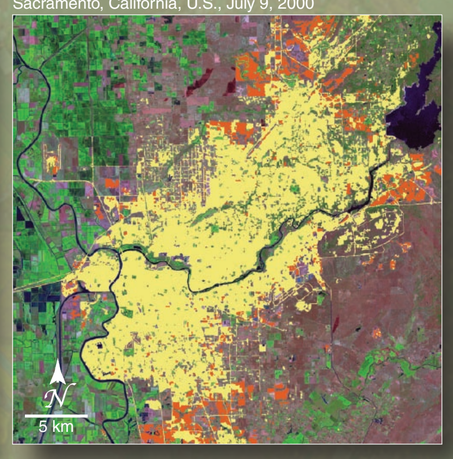
The image above shows Santa Ana wind-driven fires burning in Southern California on October 22, 2007. The top right image highlights the resulting burn scars, and shows how widespread the fires were at that time. This image combines visible and infrared light in such a way as to allow burned areas (brick red) to stand out from unburned vegetation (bright green). Desert or semi-arid landscapes are beige, dense urban areas are gray, and water is dark blue. Two of the October fires, the Witch and Harris Fires, were among the top 20 largest fires recorded since the 1930s.

Data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra satellite.

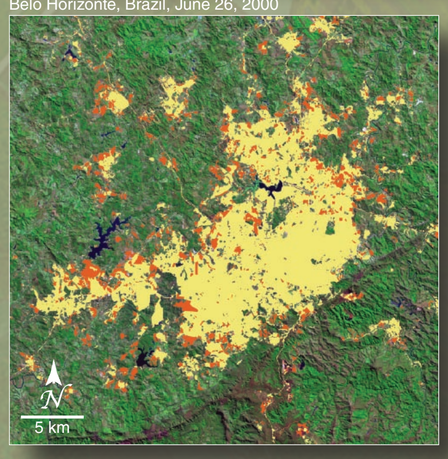
Bangalore, India, November 27, 2000



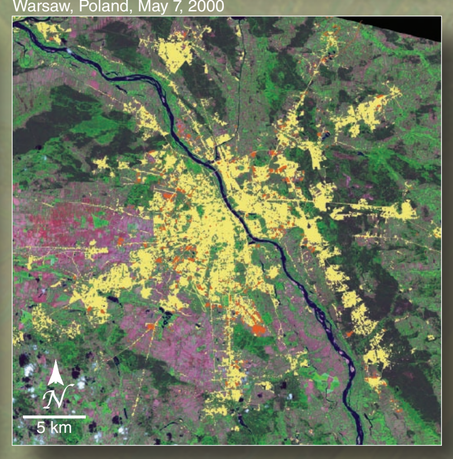
Sacramento, California, U.S., July 9, 2000



Belo Horizonte, Brazil, June 26, 2000



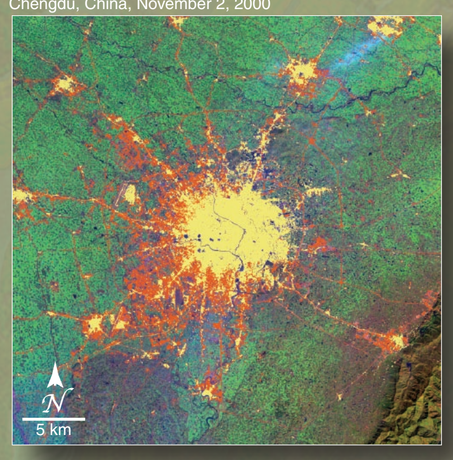
Warsaw, Poland, May 7, 2000



These five images demonstrate land use change in five major cities around the world. The base images were acquired by satellite on the dates indicated, with vegetation represented in green, water in dark blue/black, and bare ground in purple. The bright yellow map overlaid on each image indicates the extent of urban development around 1990. Orange illustrates the amount of additional urban growth between 1990 and 2000.

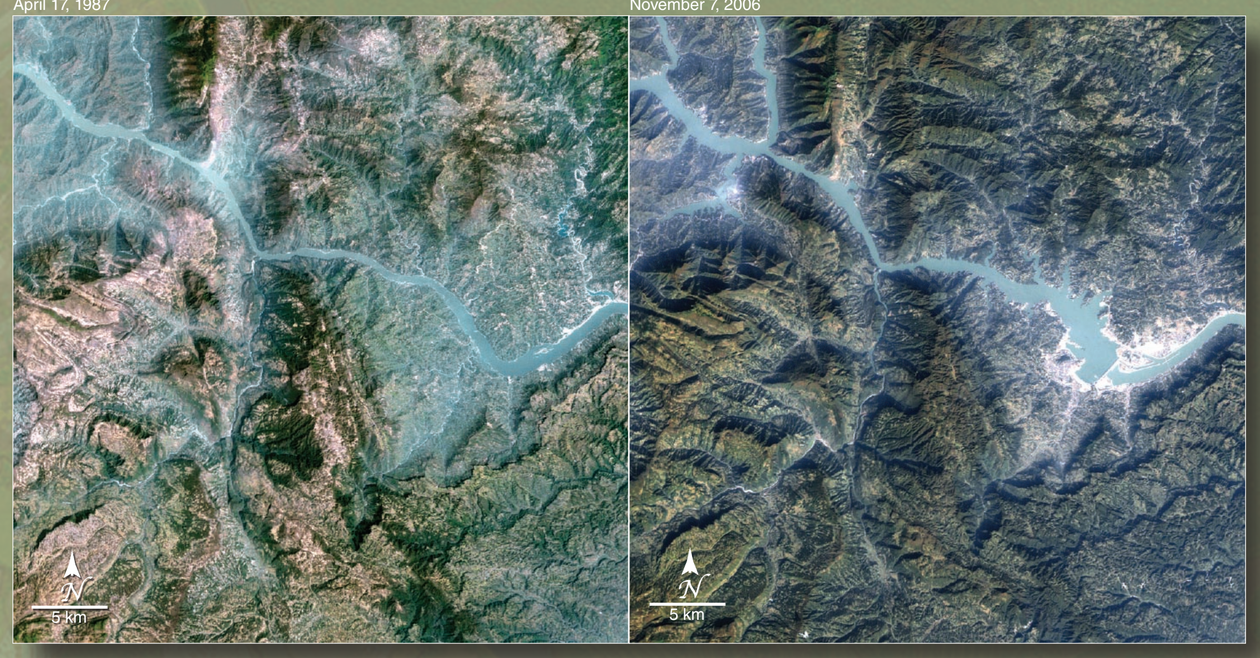
Data from the Enhanced Thematic Mapper Plus (ETM+) instrument on the Landsat 7 satellite.

Chengdu, China, November 2, 2000



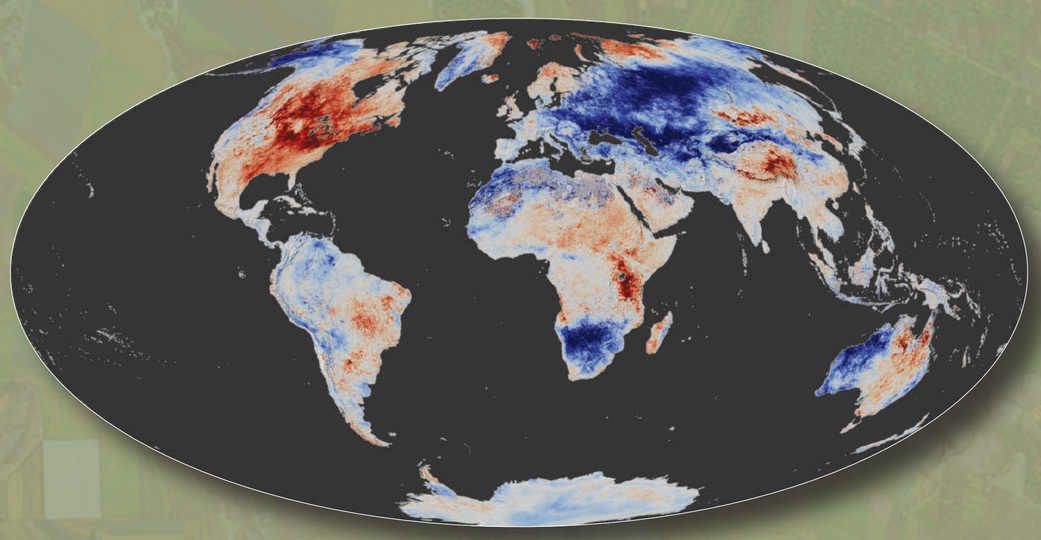
April 17, 1987

November 7, 2006



The images above show the location of the Three Gorges Dam (far right) on China's Yangtze River, the longest river in Asia. Evident here are the changes to the landscape caused by the construction. The image on the left was acquired on April 17, 1987, well before the dam project had begun. The right-hand image was acquired on November 7, 2006, after the completion of the dam's main wall. Combined satellite imagery and computer models seem to indicate that the creation of the huge reservoir of water behind the dam has altered precipitation patterns in the area, decreasing rainfall in the immediate vicinity of the dam, while increasing it farther away.

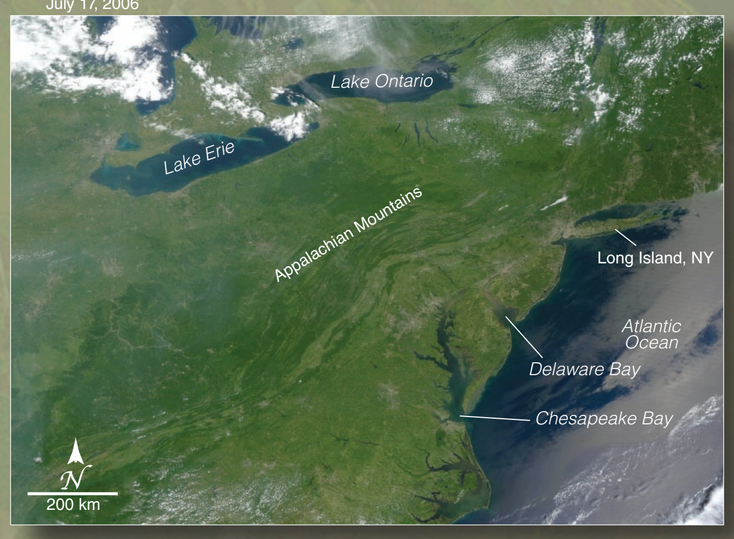
Data for left image from the Thematic Mapper (TM) instrument on the Landsat 5 satellite; data for the right image from the ETM+ instrument on the Landsat 7 satellite



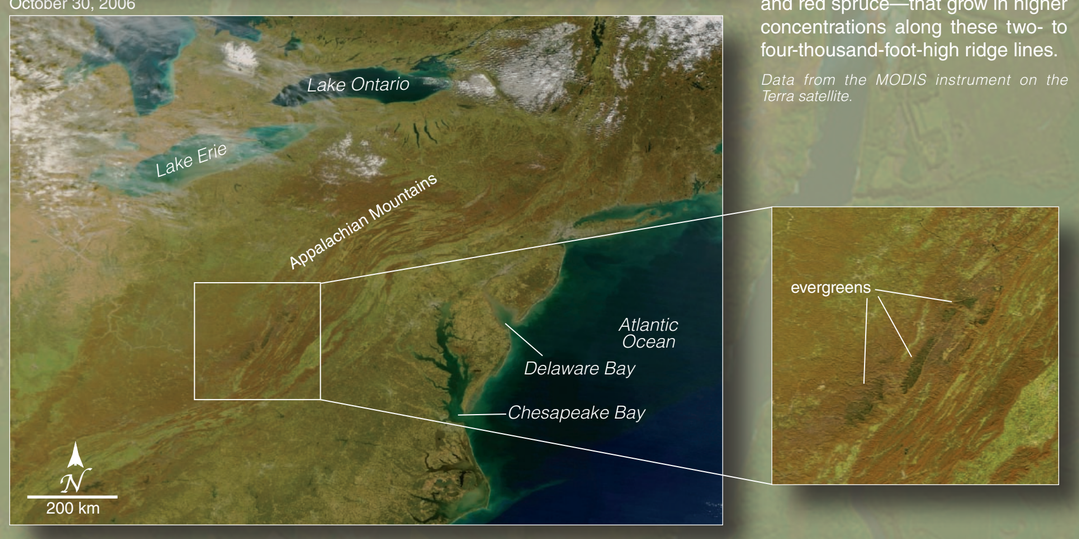
The globe above shows the difference in land surface temperature between the period of January 1-24, 2006 and average January temperatures for the period of 2001-2005. Note here that the eastern half of the U.S. was much warmer than average during January 2006. At the same time, Alaska, southern Africa, western Australia, and much of the Russian Federation were experiencing particularly cool temperatures relative to the average. These satellite measurements indicate heat emitted by the Earth's surface. This type of information can inform farmers of crop temperature, making it possible to better estimate water requirements and crop yields.

Data from the MODIS instrument on the Terra satellite.

July 17, 2006



October 30, 2006



The images at left show seasonal variation in foliage color between summer (July 17, 2006) and fall (October 30, 2006) in the mid-Atlantic and northeastern U.S. In the fall image (lower left), note the difference in color along the highest ridges in the Appalachian Mountain chain (see inset below). The deep green patches that remain among the otherwise-orange vegetation indicate the presence of evergreen trees—hemlock and red spruce—that grow in higher concentrations along these two- to four-thousand-foot-high ridge lines.

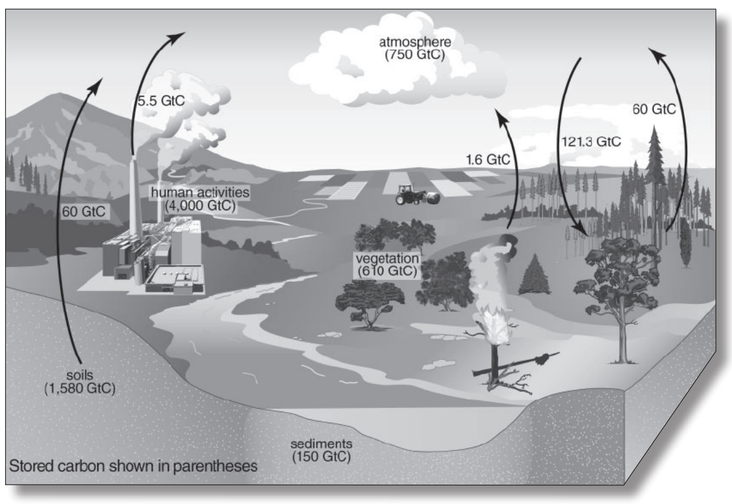
Data from the MODIS instrument on the Terra satellite.

National Aeronautics and Space Administration

Land
Our Changing Earth

NASA's Earth Observing System scientists study the Earth as a system in order to be able to predict change. All aspects of the system are actively interlinked. For example, exchanges of energy and moisture, and chemicals such as carbon dioxide, methane, nitrogen oxides, and hydrocarbons take place between the vegetation and the atmosphere. These exchanges are influenced by properties of the land, such as the underlying soils, the overlying vegetation, and land management practices, so understanding land cover changes helps us to understand the whole Earth system. Building a global picture of changes on the land, the Earth Observing System provides data on vegetation patterns, desertification, deforestation, the occurrence of fires, floods, volcanoes, and more.

A Land of Carbon



On Earth, carbon cycles between the land, oceans, atmosphere, and interior. Like an accountant that uses a ledger to track the movement of money in and out of a bank account, scientists use something called a carbon budget to track carbon as it moves through the carbon cycle.

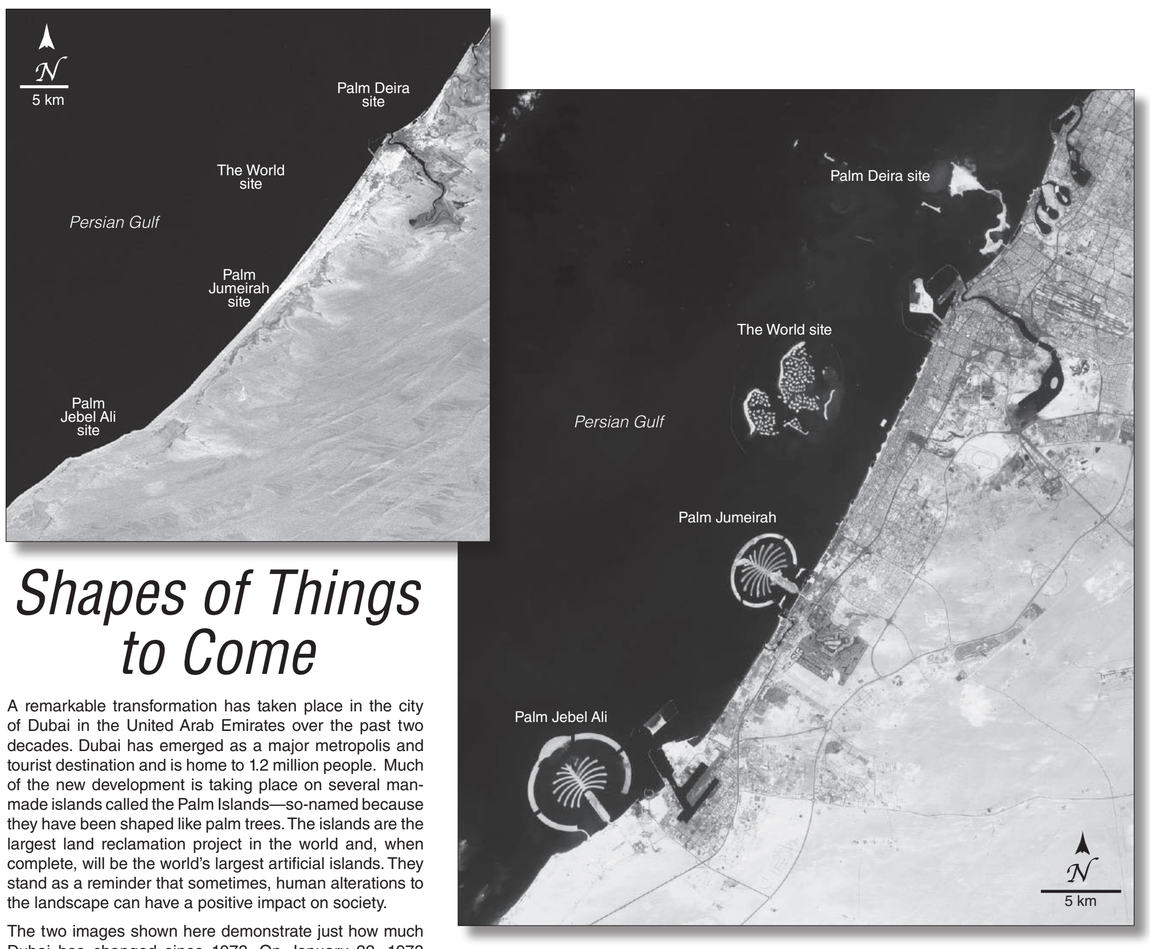
The diagram at right gives a detailed look at the sources and sinks of carbon on land in units of gigatons (billions of tons) of carbon (GtC). It illustrates that carbon storage on land is influenced by a variety of processes that occur on different time scales.

The major exchange of carbon with the atmosphere occurs during daylight hours in the growing season as the leaves of plants absorb sunlight and take up carbon dioxide from the atmosphere through the process of photosynthesis. In parallel, plants, animals and soil microbes consume the carbon in organic matter and return carbon dioxide to the atmosphere through the process of respiration.

Carbon is also stored for much longer time periods in trees and even longer in soils. When forests burn, some of that carbon is released to the atmosphere. The flames consume biomass and organic matter to produce carbon dioxide (along with methane, carbon monoxide, and smoke), and the vegetation that is killed but not consumed by the fire decomposes over time adding even more carbon dioxide to the atmosphere.

In addition to the natural fluxes of carbon through the Earth system, human activities also alter the carbon cycle. When we mine coal and extract oil from the Earth's crust, and then burn these fossil fuels for transportation, heating, cooking, electricity, and manufacturing, we are effectively moving carbon more rapidly into the atmosphere than is being removed naturally through the sedimentation of carbon, ultimately causing atmospheric carbon dioxide concentrations to increase. Also, by clearing forests to support agriculture, we are transferring carbon from living biomass into the atmosphere (dry wood is about 50% carbon).

With the use of satellites and field studies, NASA scientists will continue to learn more about the carbon cycle, how human activities might be altering it, and what implications these changes might have for climate change.



Shapes of Things to Come

A remarkable transformation has taken place in the city of Dubai in the United Arab Emirates over the past two decades. Dubai has emerged as a major metropolis and tourist destination and is home to 1.2 million people. Much of the new development is taking place on several man-made islands called the Palm Islands—so-named because they have been shaped like palm trees. The islands are the largest land reclamation project in the world and, when complete, will be the world's largest artificial islands. They stand as a reminder that sometimes, human alterations to the landscape can have a positive impact on society.

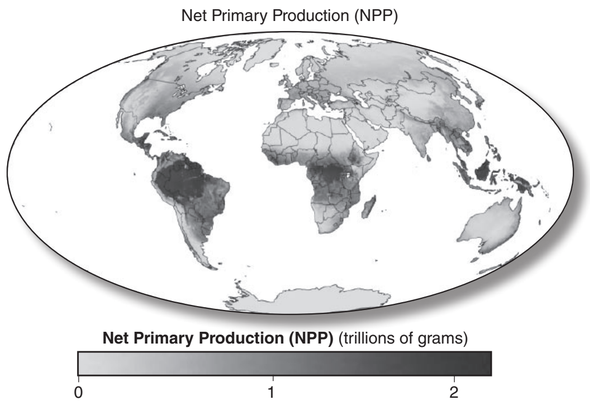
The two images shown here demonstrate just how much Dubai has changed since 1973. On January 22, 1973 (upper left), there was little evidence of human engineering of any kind. The lack of roads is evident. Very little development appears to exist along the coast. Empty sand stretches southwestward from the inlet in image center. In contrast, by October 11, 2006 (lower right), four artificial islands in various stages of development are clearly visible—note that The World site will look like a world map when it is complete—as well as plenty of evidence of human alterations to the landscape on the mainland.

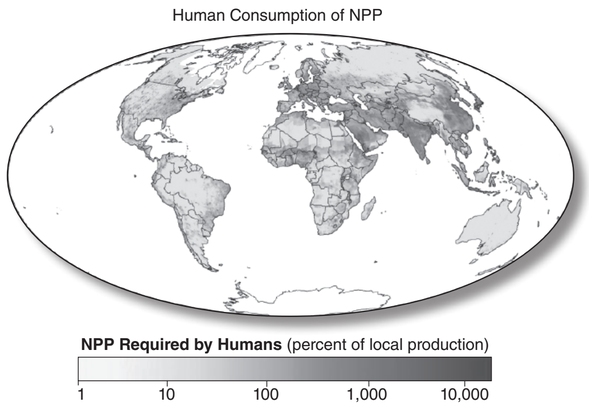
Data for the 1973 image from The Multispectral Scanner (MSS) instrument on the Landsat 1 satellite; data for 2006 from the Enhanced Thematic Mapper Plus (ETM+) instrument on the Landsat 7 satellite.

Conspicuous Consumers

Human beings have an insatiable appetite for consumption. It seems that everywhere we go, we have a way of depleting the natural environment—clearing forests, stripping the soil of nutrients, polluting streams, and so forth. Humans are particularly dependent on Earth's plant life. Plants provide the basis for all food, and much of our fuel and construction material, etc. There is rising concern as to whether the planet will be able to keep up with the ever-growing demands that society places upon Earth's limited resources.

Scientists are using satellite observations to help answer this question. Shown at right is a global map of annual average net primary production—the amount of plant material (trunks, leaves, roots, branches)) produced in the course of a year and available in a location. Not surprisingly, the greatest production is found in the tropics, where dense forests filled with many layers of plants thrive.



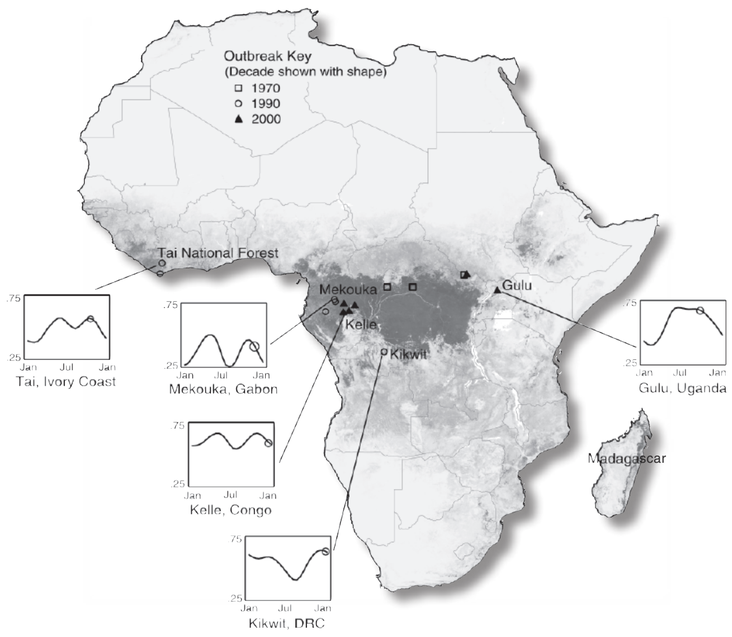


The map at left makes it clear that in many areas, human consumption far exceeds what the local environment can provide. This is true for densely populated countries like India and China. It's also true for smaller countries in areas with naturally low production, such as Saudi Arabia, and even for productive areas like the eastern United States and Europe, where levels of per-person consumption are extremely high.

Scientists speculate that the ratio of human consumption to regional net primary productivity could be an indicator of locations that are particularly vulnerable to supply disruptions, for example, as a result of natural disasters or civil unrest. Combined with models of the impacts of climate change, these studies could also help countries predict the biosphere's ability—or inability—to sustain their population's consumption levels in the future.

Data for NPP map (top left) from the Advanced Very High Resolution Radiometer (AVHRR) instrument on NOAA's Polar Orbiting Environmental Satellite series; for the map on human consumption of NPP, population data from the global population numbers and density from NASA's Socioeconomic Data and Applications Center, and global consumption data from the United Nations Food and Agricultural Organization; data for the map on NPP required by humans, data from NASA's Socioeconomic Data Center

Disease Vectors



One of the more interesting applications that NASA scientists have developed in recent years is the ability to use Earth observation data to study the spread of infectious diseases. They've looked at several diseases, such as Ebola and Rift Valley Fever, known to be more likely to spread under certain environmental conditions. Satellites are ideally suited to observe these conditions months in advance.

Temperature and precipitation are environmental factors thought to aid in the spread of these diseases. As vegetation responds to both of these factors, satellites provide information to help study their role in disease outbreaks with even greater accuracy, by measuring the Normalized Difference Vegetation Index (NDVI) as a substitute for vegetation greenness.

The map of Africa (left), which shows percentage tree cover, highlights Ebola outbreaks from several decades. A pattern that becomes clear is that Ebola outbreaks tend to occur toward the edge of a forest. When we further look at the temporal plots of NDVI for five selected locations, we see that despite a wide range of locations, all outbreaks (noted as circles on each graph) tend to occur toward the end of the rainy season, or after a seasonal peak in NDVI.

MODIS tree cover data provided by NASA's Global Land Cover Facility (GLCF); data from the MODIS instrument on the Aqua satellite

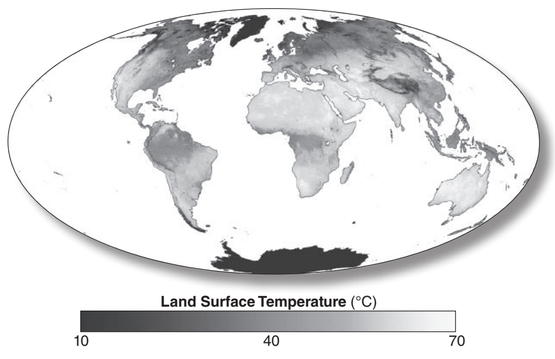
Earth's Hot Spots

Where is the hottest place on Earth? Temperature records from weather stations give that distinction to El Azizia, Libya, which hit a sweltering 57.8ºC (136ºF) on September 13, 1922, but there have likely been hotter locations beyond the scattered network of weather stations. The continuous global monitoring capabilities of NASA's Earth observing satellites can help us pinpoint those hot spots.

The globe below was created from data collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite, which flies overhead at about 1:30 p.m. local time—close to the hottest part of the day. MODIS records land surface temperatures, which reflect how hot the ground is to the touch. As anyone who has walked barefoot across a sandy beach or a slab of concrete on a summer's day can attest, the land underfoot is hotter than the air at head level. As a result, the temperatures shown here could be as much as 40ºC (104°F) hotter than the air temperatures recorded at weather stations.

This map shows the hottest land surface temperature recorded at each location on Earth between 2003 and 2005. The hottest places are lighter gray (e.g., deserts); cooler areas are darker gray (e.g., forests), and coldest areas are black (e.g., high mountains and the poles.) So back to our question: Where is the hottest place on Earth? According to MODIS, the hottest place in 2004 and 2005 was the Lut desert of Iran, which reached 70.7ºC (159ºF). In 2003, Queensland, Australia, was the hottest place on Earth, with a temperature of 69.3ºC (157ºF).

When forests are cleared away and replaced by cleared land surface for agriculture, or by the concrete, asphalt, and other building materials of urban development, the temperature of the land increases. Scientists can use land surface temperature measurements, such as those shown at right, to help them study land surface change. In the Amazon rain forest, large portions of the forest have been removed to make way for agriculture and urban development and this shows up on the satellite data. Squares of light gray intrude into the darker gray along the southern boundary of the forest. In other locations, areas with irrigated crops register as cooler than the surrounding natural vegetation because they have more water to draw upon, cooling themselves through evaporation. Looking at how land surface temperature changes over time can thus be a good indicator of the extent of irrigated agriculture and deforestation worldwide.



Life in the Big City

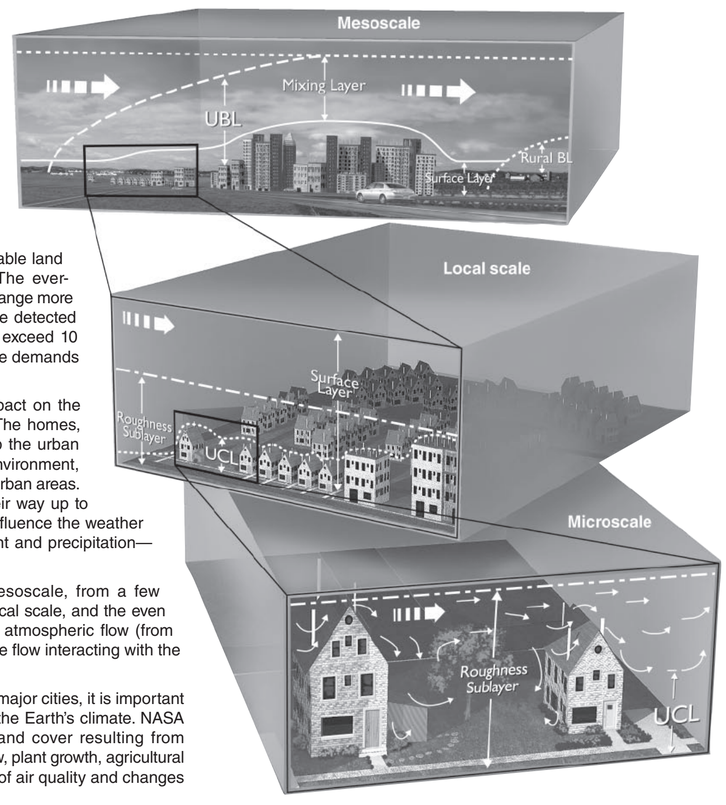
One of the more pronounced ways that human beings have changed the land surface is through the development of cities. The United Nations projects that by 2025, at least 60% of the world's population will live in cities and most of the future population growth will take place in urban areas.

Cities currently cover a little over 3% of the planets usable land area and could increase to 8% or more by 2050. The ever-expanding "concrete jungle" of urban development will change more and more of the Earth's surface and the impact can be detected from space. Some mega-cities around the world now exceed 10 million people, and these huge populations place severe demands on the planet's supply of natural resources.

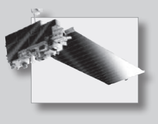
The presence of a large urban area can have an impact on the local, regional, and possibly even the global climate. The homes, buildings, and other human construction that make up the urban canopy layer (UCL) can change the heat of the local environment, as well as how the atmosphere flows in and around the urban areas. The changes begin at very small scales and work their way up to larger scales as illustrated here. These changes can influence the weather around big urban areas by affecting cloud development and precipitation—note the urban boundary layer (UBL) at top.

The three scales shown in the diagram are the mesoscale, from a few kilometers to several hundred kilometers, the smaller local scale, and the even smaller microscale. Broad arrows represent prevailing atmospheric flow (from the left here) and smaller arrows represent smaller scale flow interacting with the urban landscape.

As population continues to grow in many of the world's major cities, it is important to understand what impact these cities are having on the Earth's climate. NASA scientists continue to explore how the changes in land cover resulting from urbanization impact, land surface temperature, water flow, plant growth, agricultural production, and climate processes—e.g., deterioration of air quality and changes in rainfall patterns.



Our Changing Earth: A Mission Sampler



Terra

The Terra mission, launched in December 1999, carries five instruments, three of which provide significant contributions to land studies: the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), the Multi-angle Imaging Spectroradiometer (MISR), and the Moderate Resolution Imaging Spectroradiometer (MODIS).

ASTER obtains high-resolution image data over targeted areas of the Earth's surface, as well as black-and-white stereo images. ASTER provides the capability for repeat coverage of changing areas on the Earth's surface with spatial resolutions of between 15 and 90 meters (49.2 and 295.2 feet) and augments the Landsat database, which was started in 1972. Together, the Landsat and ASTER data provide scientists with the ability to determine the rates that glaciers are advancing or receding.

MISR measures the amount of sunlight that is scattered in different directions under natural conditions, using nine cameras mounted at different angles. As the instrument flies overhead, the Earth's surface is successively imaged by all nine cameras. Scientists are using MISR data to develop new methods for mapping vegetation cover based on the vertical structure of plants.

MODIS provides a comprehensive series of global observations every one or two days at spatial resolutions of up to 250 meters (820 feet). Scientists can now provide global maps to ascertain changes in vegetation type, extent and productivity. MODIS can also be used to monitor the extent of frost or drought damage to croplands over large areas. Such maps are also needed to determine the overall health and status of agricultural crops throughout the growing season. This information is vital for monitoring the world's food resources. MODIS has also been useful in monitoring volcanic activity and fires and has been helpful in determining land surface temperature.

Aqua

The Aqua mission, launched in May 2002, carries six instruments, four of which provide significant contributions to land studies. These four are MODIS, also on the Terra satellite (see above), the Atmospheric Infrared Sounder (AIRS) and its companion Advanced Microwave Sounding Unit (AMSU), and the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E). AIRS/AMSU data can be used for calculating land surface temperature, while AMSR-E data have been used in detecting and analyzing extreme flood events and in obtaining indications of soil moisture.

Landsat 7

Landsat 7 is the latest in a series of satellites that have provided a continuous set of essential land surface data to both national and international users since 1972. The Landsat 7 system collects and archives an unprecedented quantity of high-quality multispectral data each day, enabling scientists to monitor agricultural productivity, urban growth, and land cover change, as well as volcanoes, glacier dynamics, and coastal conditions, and providing data needed for oil, gas, and mineral exploration. While NASA's other EOS instruments MODIS and MISR acquire frequent, coarse views of land-cover change, the spatial resolution of data from the Enhanced Thematic Mapper Plus (ETM+) instrument on Landsat 7 allows researchers to determine the actual causes of observed land cover changes. These changes have important implications both for local habitability and the global cycling of carbon, nitrogen, and water.

LDCM

The Landsat Data Continuity Mission (LDCM) is the successor to Landsat 7. It is scheduled for launch after July 2011. LDCM will detect both natural and man-made changes on the surface of the Earth. These continuing observations are key in the study of land use and land cover change, global climate research, and polar studies.

SMAP

The Soil Moisture Active-Passive mission will measure surface soil moisture, which is useful in improving our ability to forecast weather, flood and drought events, and to predict agricultural productivity and climate change. It's proposed launch date is between 2010 and 2013.

DESDynI

The Deformation, Ecosystem Structure and Dynamics of Ice mission will help determine the potential for earthquakes, volcanic eruptions, and landslides. It will also be useful in monitoring the effects of land use on species habitats and the carbon budget, as well as helping to better study the responses of the Earth's ice sheets to climate change and resulting impacts on global sea level.

NW-2007-8-058-GSFC