National Aeronautics and
Space Administration

Understanding Earth
Biodiversity & Ecological Conservation

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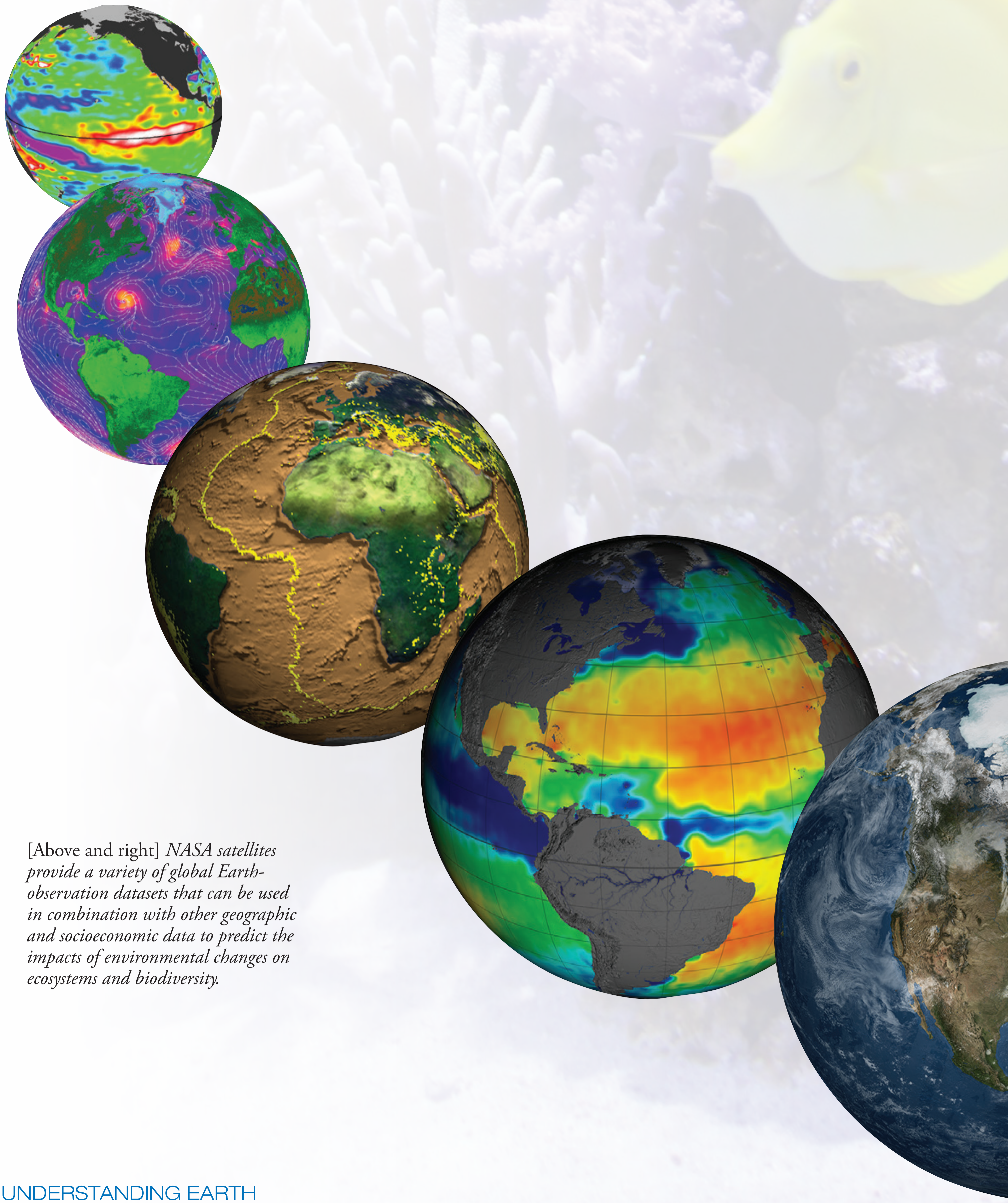
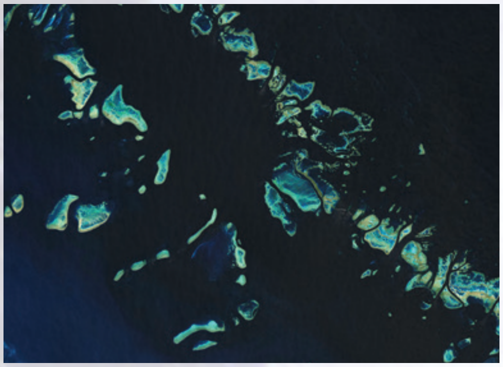


[Above and right] *NASA satellites provide a variety of global Earth-observation datasets that can be used in combination with other geographic and socioeconomic data to predict the impacts of environmental changes on ecosystems and biodiversity.*

UNDERSTANDING EARTH

Biodiversity & Ecological Conservation



Credit: NASA's Earth Observatory

***On the cover**: The Great Barrier Reef off the northeast coast of Queensland, Australia, is the world's largest reef system and one of the richest and most biodiverse natural ecosystems on Earth. Spread across 346,000 square kilometers (134,000 square miles) of the Coral Sea, it comprises 2,500 individual reefs, more than 900 islands. This natural wonder has been facing multiple threats, including ocean acidification and warming sea surface temperatures that cause coral bleaching.*

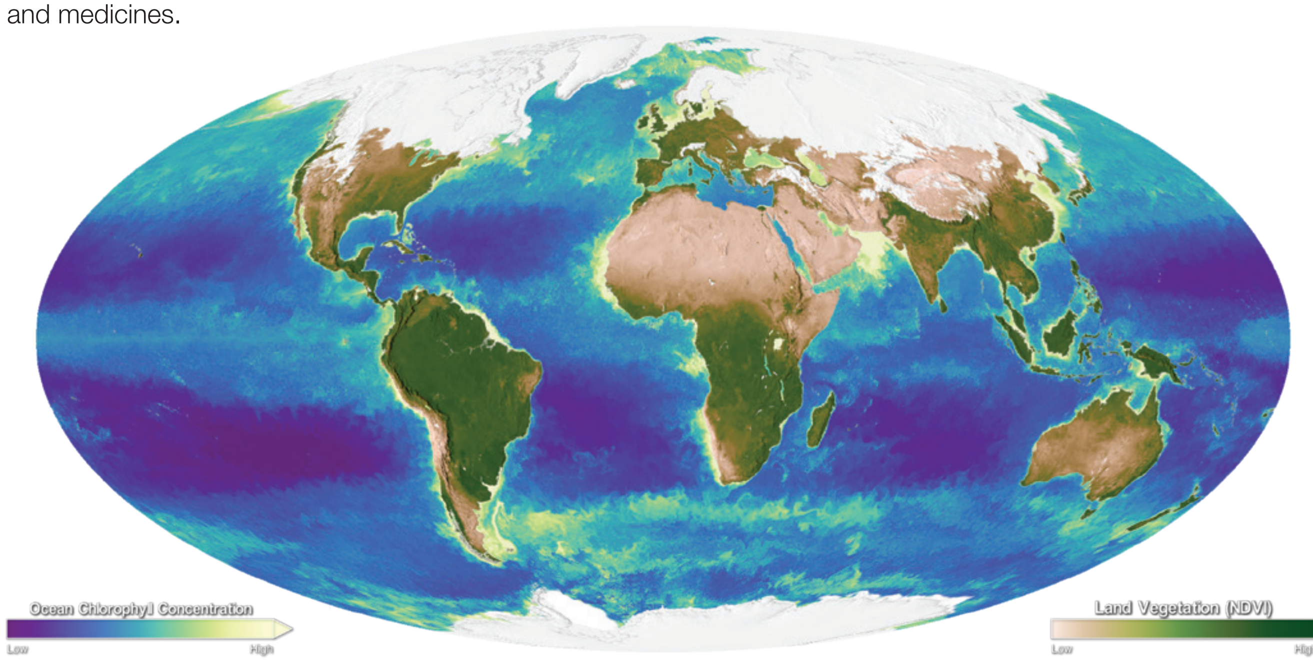
Image credits: NASA, James N. Stuart, U.S. Fish and Wildlife Service, Craig Bennett, Elvis Payne

[Above] *Biodiversity is the life-support system for Earth and encompasses all life forms, on all levels.*

What is Biodiversity?

Earth supports a diverse spectrum of life. Over billions of years, life has evolved into a variety of forms—from microorganisms to our own species—reflecting the rich array of environmental conditions present on our changing planet.

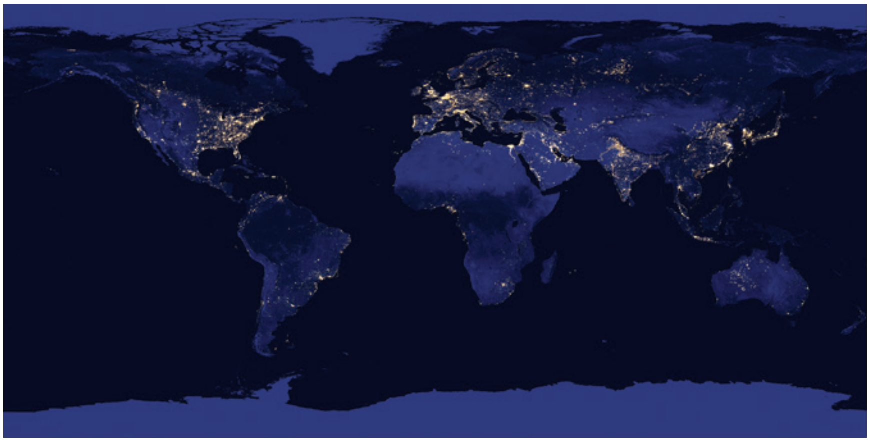
Biological diversity, or *biodiversity*, refers to the variety of all life on Earth—on all levels, from genes to species, ecosystems, and biomes. While it is believed that Earth supports approximately 3 to 10 million species, only about 1.5 million have been given a scientific name. Biodiversity is critical for maintaining balanced ecosystems and provides a plethora of ecosystem goods and services such as clean air, fresh water, waste removal, food, fiber, and medicines.



Credit: NASA's Scientific Visualization Studio

[Above] *Scientists use data from the Suomi NPP VIIRS satellite sensors to study the abundance of life both on land and in the sea. In this image from May 2021, dark blue colors in the ocean represent warmer areas where there is little life due to lack of nutrients, while yellow and orange represent cooler nutrient-rich areas. The nutrient-rich areas include coastal regions where cold water rises from the sea floor bringing nutrients along and areas at the mouths of rivers where the rivers have brought nutrients into the ocean from the land. On land, green represents areas of abundant plant life, such as forests and grasslands, while tan and white represent areas where plant life is sparse or non-existent, such as the deserts in Africa and the Middle East and snow-cover and ice at the poles.*

Credit: NASA's Earth Observatory



[Left] *This image depicts the Earth at night as observed by the Visible Infrared Imaging Radiometer Suite's (VIIRS) "day-night band" onboard the Suomi National Polar-orbiting Partnership (NPP) spacecraft. Scientists use night-lights imagery from VIIRS to study the spatial distribution of humans on the planet, as well as changes in sky brightness over time. Nocturnal animals can become disoriented by light pollution, and other animals may change their mating, migration, and feeding habits.*

Earth's biodiversity is not evenly distributed. Regions near the equator for example, tend to be more biodiverse than higher-latitude, colder regions. Environmental parameters such as temperature, precipitation, elevation, nutrient availability, and salinity influence the number and type of species found in a region.

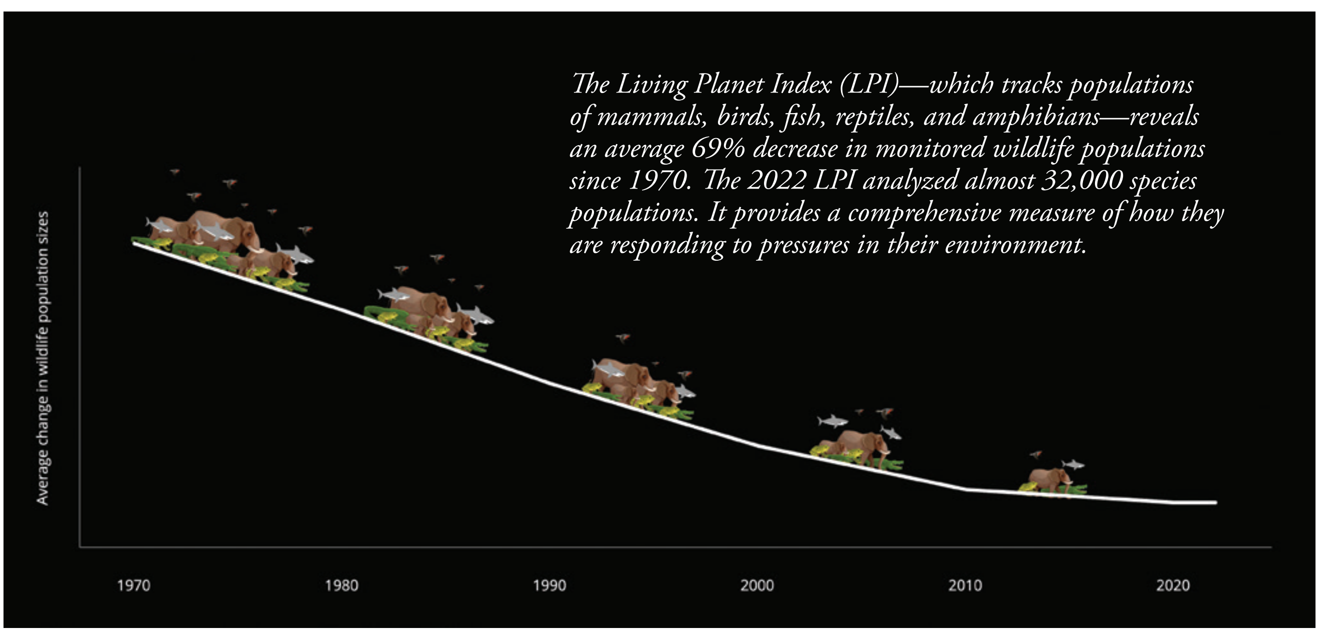
Humans also impact biodiversity. As of 2023, more than eight billion people share our planet and place ever-increasing demands on its resources. To meet our needs, humans are altering environments and extracting resources from terrestrial, marine, and freshwater ecosystems.

Over the last several decades, research has shown that global biodiversity has been on the decline. While both natural and human-induced disturbances influence biodiversity, most contemporary biodiversity loss stems from the impact human activities have on the environment. Habitat changes resulting from these human activities are the key driver of biodiversity loss. The causes of biodiversity loss include the conversion of natural habitats, increasing resource extraction, pollution, invasive species, and a changing climate.

BIO FACT: *Overfishing, water pollution, and increased runoff from agriculture are taking a toll on coral and other aquatic life.*

BIO FACT: *Data from remote sensing instruments are used to map, track, and assess the ecological and biophysical impacts of both terrestrial and aquatic invasive species.*

Credit: World Wildlife Fund



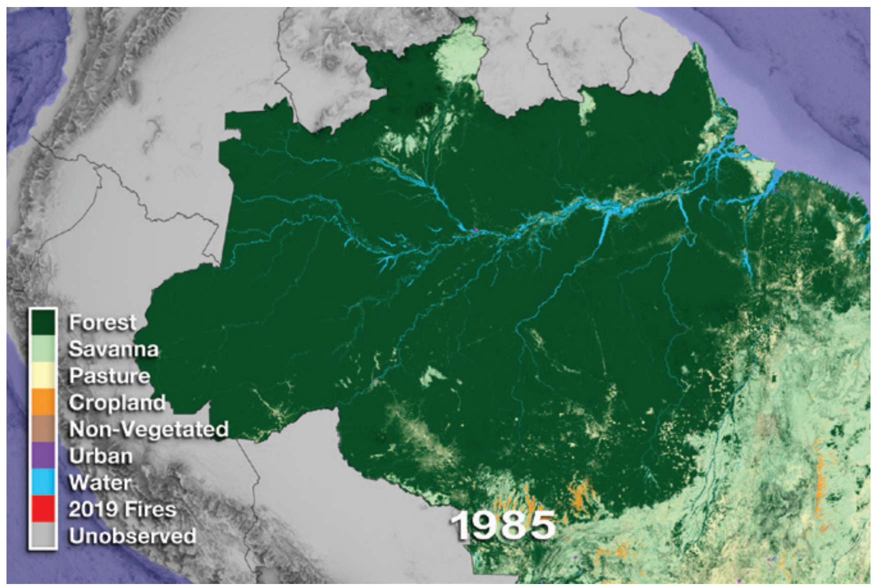
The Living Planet Index (LPI)—which tracks populations of mammals, birds, fish, reptiles, and amphibians—reveals an average 69% decrease in monitored wildlife populations since 1970. The 2022 LPI analyzed almost 32,000 species populations. It provides a comprehensive measure of how they are responding to pressures in their environment.

Observing Environmental Changes that Impact Biodiversity

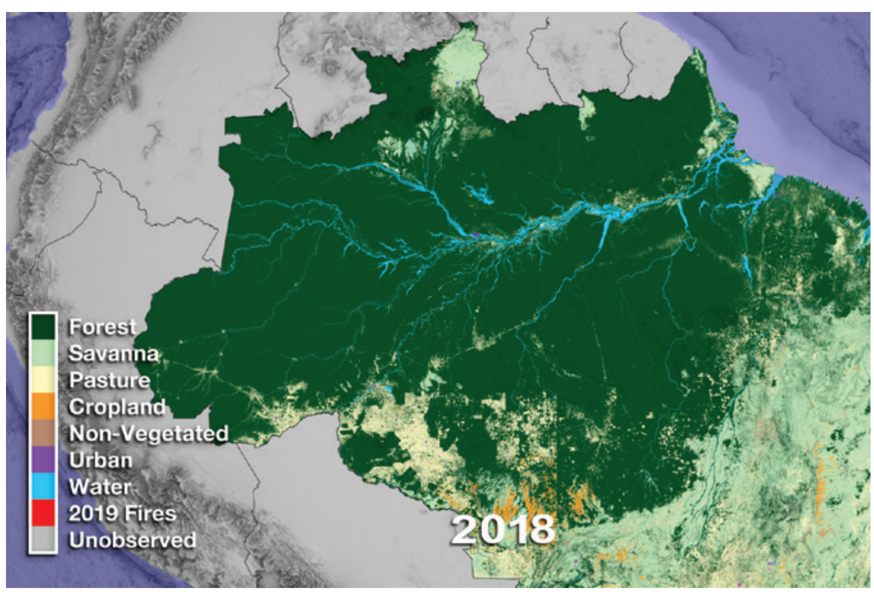
The vantage point of space provides a unique perspective to observe Earth's surfaces at local, regional, and global scales, as well as over time. For decades, satellite and airborne remote sensing instruments have been observing environmental changes that impact biodiversity including: increases in deforestation, increases in urban expansion, a rise in global temperature, and a decline in Arctic sea ice extent. Environmental changes are interrelated and have positive and negative, as well as short- and long-term effects on Earth's biodiversity. Furthermore, changes in Earth's climate can accelerate and amplify other environmental changes, causing subsequent changes in biodiversity.

Satellite observations—often combined with other measurements taken on the ground or from aircraft—can also provide information relevant to the distribution of ecosystems and their resident species.

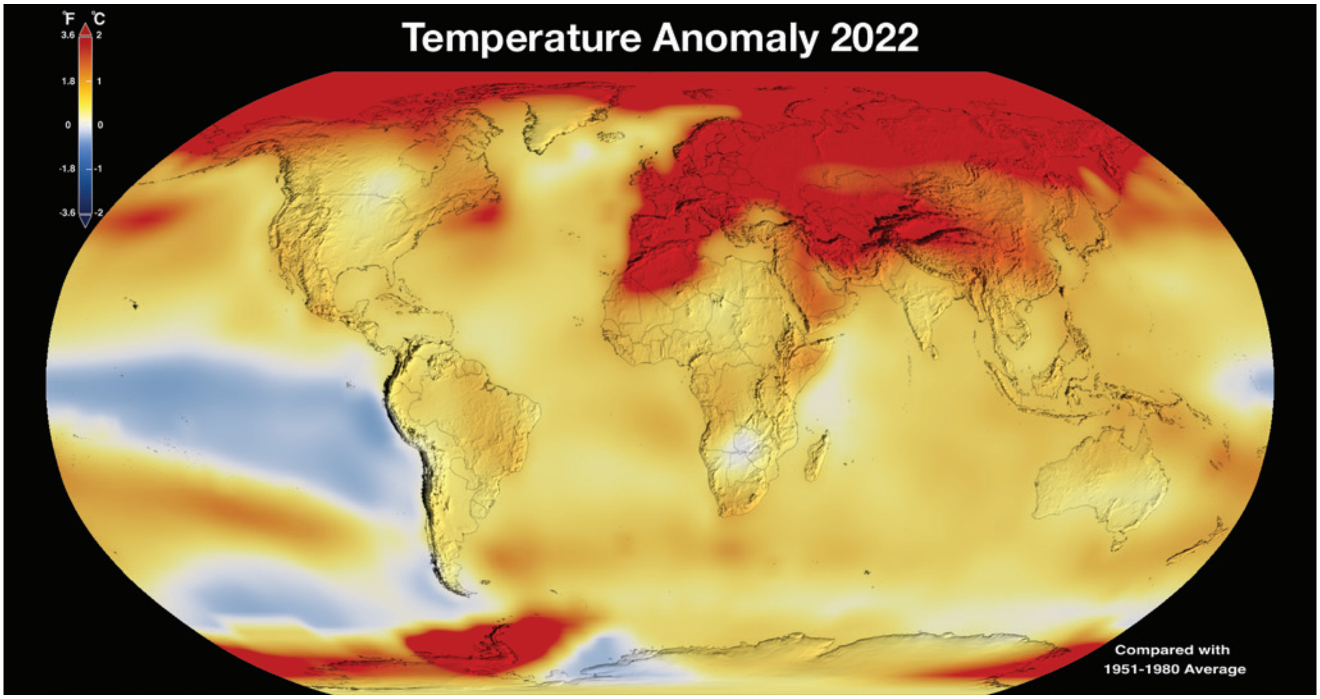
[Right] *The Amazon rainforest, the largest rainforest in the world, has undergone major transformations in recent decades. Working closely with their Brazilian counterparts, NASA scientists have mapped the entire country of Brazil to show different kinds of land use throughout the country. These new data are based on the Landsat Data Continuity Mission (LDCM).*



BIO FACT: *Dams and other hydro-engineering projects can result in habitat loss for freshwater aquatic species, as well as disrupt movement and migration patterns that are critical for maintaining healthy populations.*



Credit: NASA's Scientific Visualization Studio

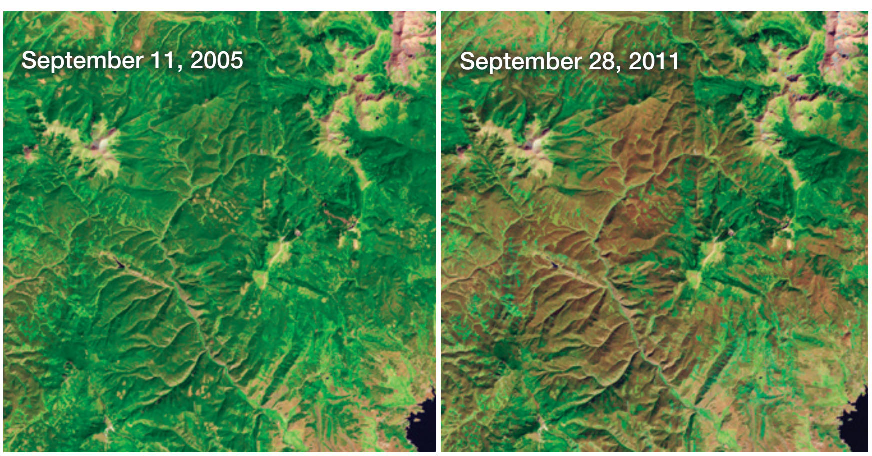


Credits: NASA's Scientific Visualization Studio

[Above] *This map shows the 2022 global surface temperature anomaly compared with the 1951-1980 average. Earth's global average surface temperature in 2022 tied with 2015 as the fifth warmest on record, according to an analysis by NASA. Continuing the planet's long-term warming trend, global temperatures in 2022 were 1.6 degrees Fahrenheit (0.89 degrees Celsius) above the average for NASA's baseline period (1951-1980), scientists from NASA's Goddard Institute for Space Studies (GISS) reported.*

Photo credit: Ron Long, Simon Fraser University

[Above] *Photograph of a mountain pine beetle.*



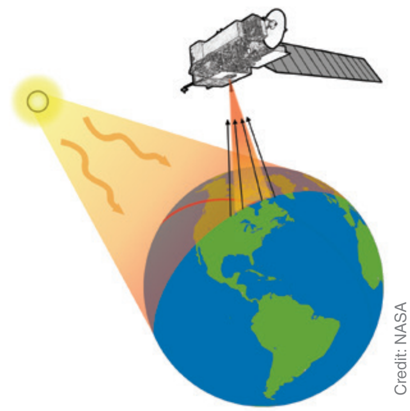
[Above] *Warmer winters and drier summers across the Rocky Mountains have led to an increase in mountain pine beetle outbreaks. This pair of images from the Landsat-5 satellite reveals beetle damage in Rocky Mountain National Park in Colorado. In 2005* [left] *healthy forests appeared bright green. Just six years later in 2011* [right], *many of the bright green areas appear drab brown, indicating portions of the forest that have been attacked by the mountain pine beetle. While pine beetles in the Western United States are a native species and part of natural-disturbance dynamics, changes in Earth's climate may increase the number of pine beetle infestations, resulting in the loss of habitat for numerous species.*

[Above] *The Landsat program—jointly managed by NASA and the United States Geological Survey—has provided continuous coverage of the global land surface since 1972. Landsat satellites use passive remote sensors to measure reflected light in visible and infrared wavelengths. Launched in September 27, 2021 from Vandenberg Space Force in California, Landsat 9 continues the Landsat program's critical role in monitoring, understanding and managing the land resources needed to sustain human life. Landsat imagery is available to all users free of charge.*

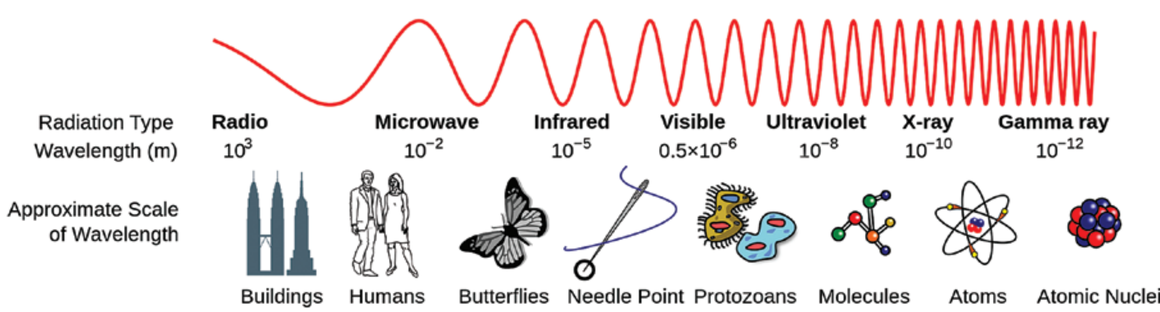
Using Earth Observations to Understand Biodiversity

NASA is working in collaboration with experts from other federal agencies, universities, private companies, non-governmental organizations, and international institutions to study patterns of biodiversity and understand how biodiversity is changing. In particular, they are using both passive and active satellite and airborne remote sensing technologies to directly observe and identify biodiversity patterns, such as the distribution of ecosystems and vegetation structure, as well as the environmental parameters that influence them such as topography and climate conditions. Together, these observations strengthen our understanding of ecosystem function and Earth's biodiversity.

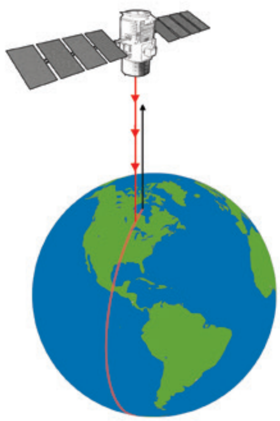
Passive remote sensors detect natural energy that is reflected or emitted from the Earth. Scientists use a variety of passive remote sensors including radiometers, spectrometers, and spectroradiometers to observe and monitor biodiversity. These sensors record electromagnetic energy at different wavelengths, often outside of the visible light range. This allows scientists to "see" beyond what our human eyes alone can see and "tune in" to various characteristics of the Earth's surface. Passive remote sensing measurements can be used to identify different communities and ecosystems in both terrestrial and aquatic environments. Different vegetation types for example, have distinct reflection "signatures" in the electromagnetic spectrum that scientists observe and analyze to classify plant groups. Likewise, scientists use passive remote sensors to observe and monitor environmental parameters that influence biodiversity such as soil type, surface temperature, levels of ocean surface chlorophyll a, and sea ice concentrations.



[Above] *Passive remote sensors detect natural energy that is reflected or emitted from the observed scene.*



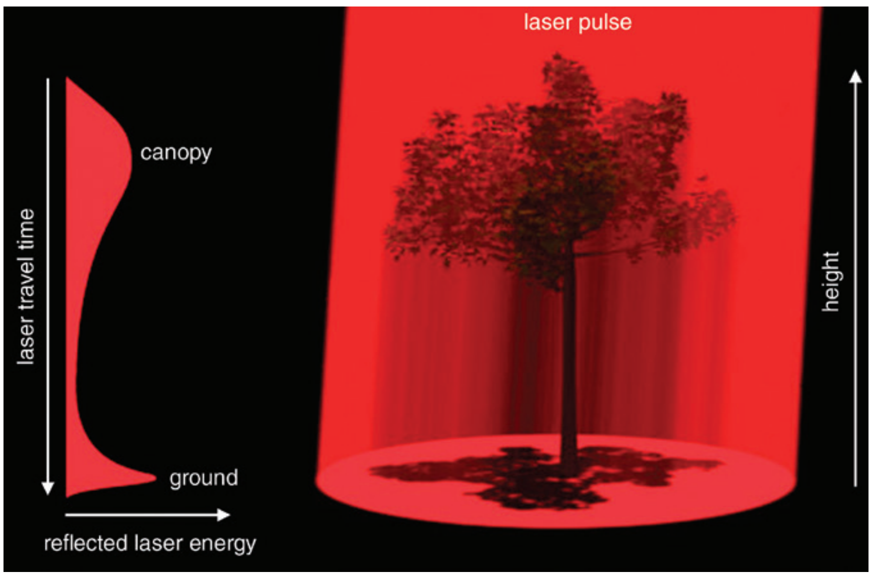
[Above] *The electromagnetic spectrum is the range of traveling waves of energy that include gamma and x-rays, ultraviolet light, infrared radiation, microwaves, and radio waves. Human eyes are adapted to see a narrow band of this spectrum called visible light. Soils, different plant types, water, bare rock, ice, and many other types of land cover each have their reflected or emitted "signatures" in the electromagnetic spectrum and scientists can observe and analyze these reflectances or emissions to detect changes in the land surface.*


Credit: NASA

[Above] *Active remote sensors emit energy (i.e., electromagnetic radiation) and then receive the radiation that is reflected or backscattered from that object.*

Active remote sensors emit energy to illuminate the object or scene they observe. They send a pulse of electromagnetic energy from the sensor to the object and then receive the electromagnetic radiation that is reflected or backscattered from that object. Among these active remote sensors are radars (i.e., radio detection and ranging), lidars (i.e., light detection and ranging), scatterometers, and laser altimeters. Scientists often use these sensors to observe three-dimensional structure that directly affects biodiversity, such as canopy height and distribution of vegetation in the canopy and the understory. In aquatic environments, active sensors can measure characteristics such as suspended sediment concentrations and ocean surface wind speeds.

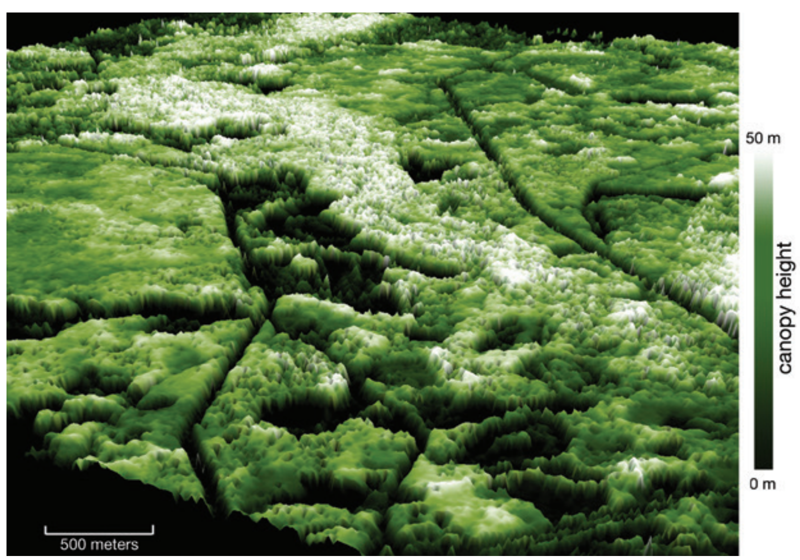
By combining satellite and airborne measurements from both passive and active sensors with ground-based measurements, scientists can estimate the distribution of and changes in biodiversity at all levels and on all scales.



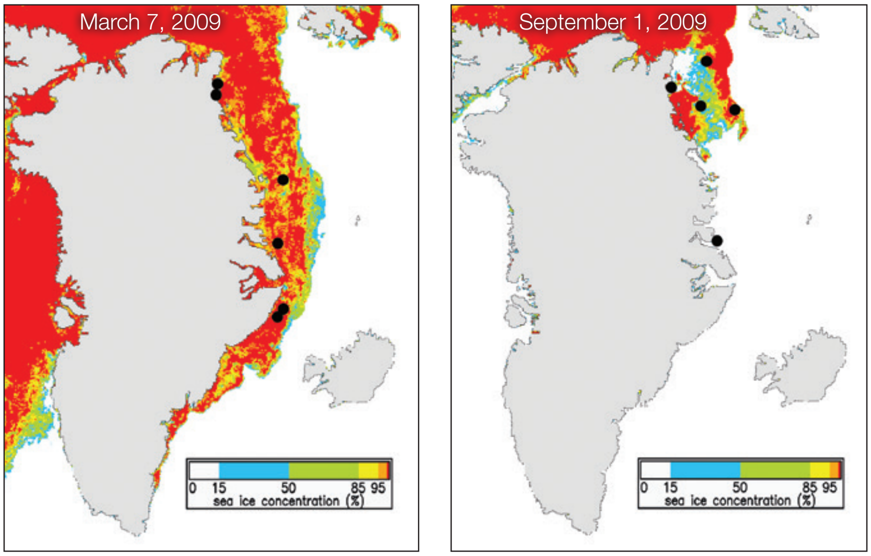
Credit: NASA

[Left] *Lidar instruments provide information about the three-dimensional distribution of vegetation by emitting a laser pulse of light and measuring the elapsed time of the return signal. Data from multiple returns can provide information on the height of the canopy, ground, and other layers of vegetation. When combined with field data, lidar measurements can then be used to calculate above ground biomass over large areas.*

[Right] *This image, created with airborne lidar data from a NASA instrument, shows tree heights at an oblique angle across the Patuxent Wildlife Refuge Research Center in Laurel, Maryland. Scientists use canopy-height data such as these, combined with other remotely sensed vegetation measurements and field surveys of bird richness and abundance, to understand and spatially predict patterns of bird diversity.*



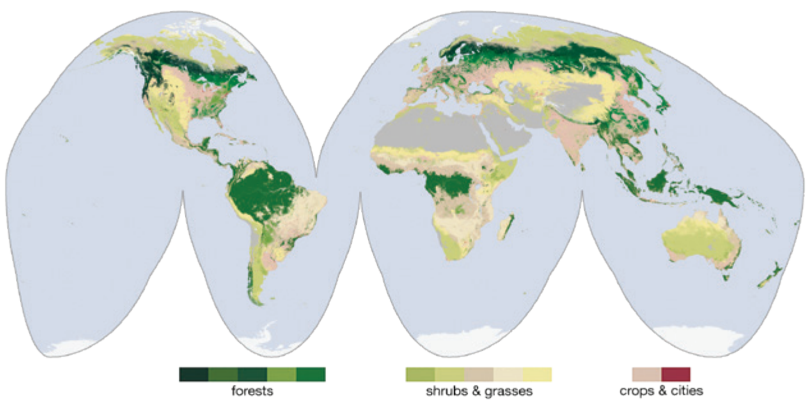
Credit: Scott Goetz, Woods Hole Research Center



Credit: Kristin Laidre, University of Washington

BIO FACT: Scientists have discovered that above ground vegetation biomass in the Arctic has increased nearly 20% from 1982 to 2010.

[Left] *NASA-funded scientists combined animal tracking data with sea ice concentration data to observe habitat selection and migration patterns to study the impacts of changes in climate on Arctic mammals. These two images show the location of polar bears (black dots) in East Greenland on March 7, 2009* [left], *the month when sea ice typically reaches its maximum extent, and on September 1, 2009* [right], *the month when sea ice typically reaches its minimum extent. Polar bears require sea ice to catch seals, their main prey. As sea ice retreats during warmer months some polar bears move north and stay on the receding ice, while others go on land. Declining sea ice has been linked to declines in the health of individual polar bears and the abundance and survival of polar bear sub-populations. Research like this can help identify the impacts of climate change and understand how loss of sea ice will impact various sub-populations. Sea ice concentrations were derived from Advanced Microwave Scanning Radiometer for EOS (AMSR-E) data from NASA's Aqua satellite.*



Credit: NASA

[Above] *Created with data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instrument onboard the Terra and Aqua satellites, this map shows global land cover classification types. Data from MODIS are widely used to study patterns and changes in land cover as well as changes in vegetation "greenness," important when studying the health of forests, grasslands, and other vegetation types.*

BIO FACT: Satellite missions such as the Global Precipitation Measurement (GPM) Core Observatory and Soil Moisture Active Passive (SMAP) provide precipitation and soil moisture data that will help us better understand and predict changes in the global water cycle, critical for studying changes in biodiversity.

PACE

PACE is NASA's Plankton, Aerosol, Cloud, ocean Ecosystem mission that will advance the assessment of ocean health by measuring the distribution of phytoplankton, tiny plants and algae that sustain the marine food web. It will also continue systematic records of key atmospheric variables associated with air quality and Earth's climate.

Credit: NASA

[Left] *Artist's rendition of the PACE spacecraft.*

Photo credits: ribbla (morgueFile.com), D. F. McLean, Anthony Kelly, Rene Cunningh

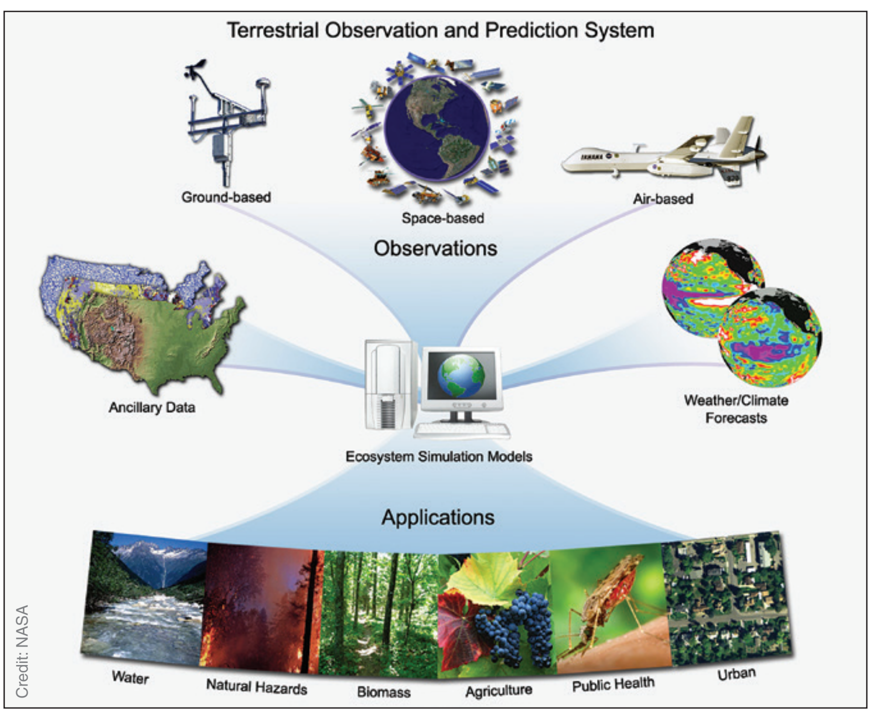
[Above] *Humans experience changes in biodiversity as changes in ecosystem services. For example, humans rely on a variety of fruits, vegetables, and animal-based products to maintain a healthy diet; harvested wood to build homes, furniture, and other consumer goods; and plant extracts to treat illnesses and soothe symptoms. All of these benefits to people stem from biodiversity.*

Conserving Biodiversity through Ecological Forecasts

Biodiversity is the life support system of our planet. To conserve our planet's rich biodiversity the scientific community must observe our world as one large, interactive, connected system. At NASA, scientists use environmental models to combine various Earth observations, such as land cover, precipitation, and/or sea surface temperature with a variety of ground-based measurements such as animal population data to generate *ecological forecasts*.

Ecological conservation allows scientists to project the future impacts of environmental changes. The goal is to develop reliable, science-based information that allow decision makers to proactively plan effective resource management strategies as well as explore the anticipated outcomes of alternative strategies. In particular, decision makers use ecological forecasts to actively address issues related to biodiversity conservation, protected area management, and marine fisheries. Management actions can reduce or eliminate the impacts of environmental change on biodiversity, which in turn has significant socioeconomic implications.

The NASA Applied Sciences Program's Ecological Conservation applications area promotes the development of innovative decision-support tools that use Earth observations. These projects are developed with and transitioned to partner agencies and organizations such as the United States Geological Survey, United States Fish and Wildlife Service, National Park Service, National Marine Fisheries Service, and Appalachian Trail Conservancy, with the objectives of better managing and conserving biodiversity today and in the future.



[Left] *Scientists use Earth observations to understand current and future ecosystem conditions for use in research and applications. Harmonizing multiple sources of data from satellite, aircraft, and ground-based sensors is key to creating useful and usable models and predictions.*

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Resources

NASA Biological Diversity Program & Ecological Conservation Applications Area
cce.nasa.gov/biodiversity

NASA Applied Sciences Program
appliedsciences.nasa.gov

NASA's Earth Observing System Data and Information System
earthdata.nasa.gov

Contacts

Biological Diversity Program Ecological Conservation Applications Area Program Managers

Woody Turner (*woody.turner@nasa.gov)*

Keith Gaddis *(keith.gaddis@nasa.gov)*

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