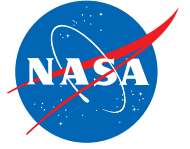
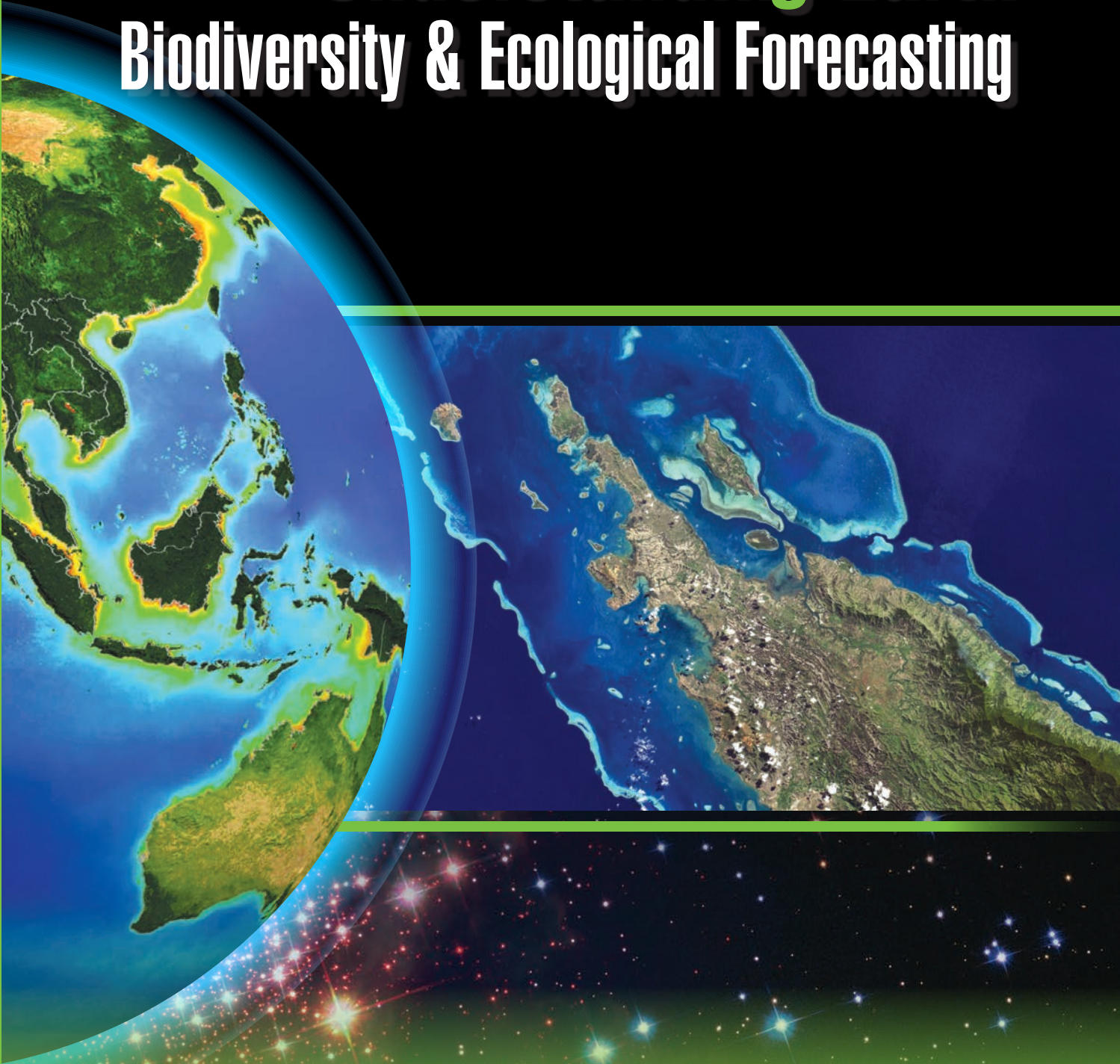


National Aeronautics and  
Space Administration



# Understanding Earth Biodiversity & Ecological Forecasting

Understanding Earth | Biodiversity & Ecological Forecasting





*This false-color image from Landsat 7 shows the Matang Mangrove Forest on December 27, 1999—an important nursery for fish and other aquatic life, as well as a critical habitat for many birds. The reserve is the largest tract of mangrove forest in peninsular Malaysia and is also an example of a sustainably managed mangrove forest. The thick vegetation of the reserve (green) stands out clearly from surrounding land that has been cleared for agriculture and towns (pink). Credit: NASA's Earth Observatory*

# UNDERSTANDING EARTH Biodiversity & Ecological Forecasting



Credit: NASA's Earth Observatory

***On the cover:** Located approximately 1200 kilometers (750 miles) east of Australia, the coral reefs around New Caledonia support an unusual diversity of species, including large numbers of predators and other big fishes, turtles, and dugong. This image, taken by Landsat 7 on May 10, 2001, shows the coral reefs that surround New Caledonia's main island, Grande Terre.*



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.*

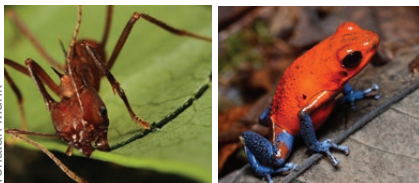
[Below] *Tropical rainforests and coral reefs are two of the most biodiverse biomes on the planet and provide habitats for thousands of species.*



Jim Maragos/U.S. Fish and Wildlife Service



Sim Eng Hiang



Yonatan Munk

Geoff Gallice

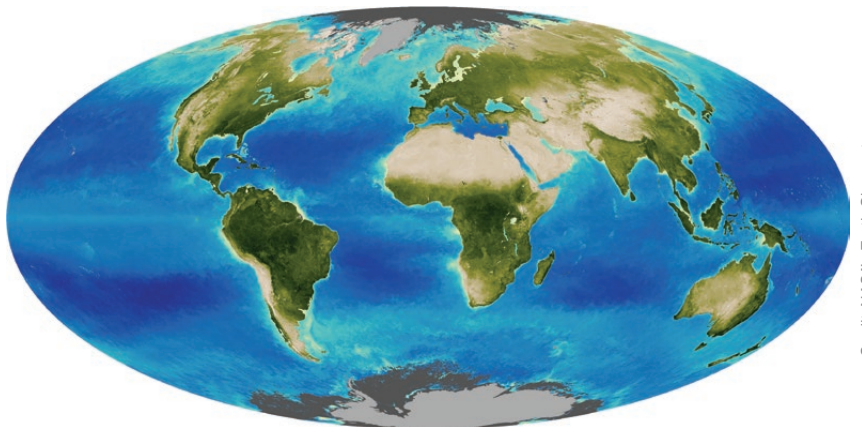


Photo credits: Rachel Sarai

## 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.

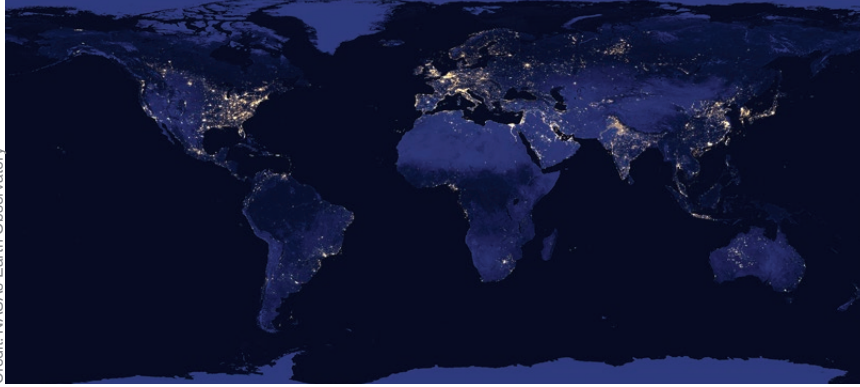


Credit: NASA's Earth Observatory



[Above] *Made with ocean chlorophyll data collected by NASA's Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite and vegetation data collected by satellites operated by the National Oceanic and Atmospheric Administration, this map shows the average density of plant growth on land and concentration of chlorophyll near the surface of the oceans in 2008. The darkest green areas, where plant growth is greatest, tend to be concentrated in tropical regions around the equator. Over oceans, average annual chlorophyll concentrations are highest near the poles or regions where wind and upwelling ocean currents bring cold, nutrient rich water to the surface, such as around the equator and along the shores of continents.*

Credit: NASA's Earth Observatory



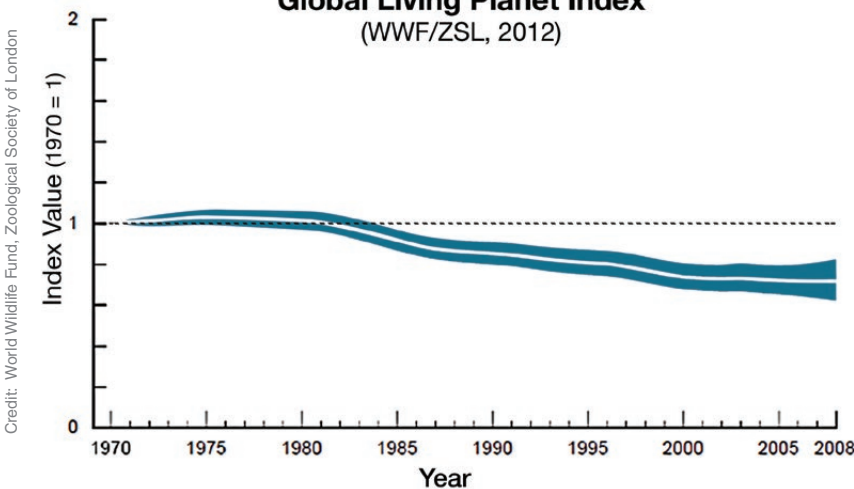
[Above] Human population surpassed seven billion in 2011 and the United Nations expects it to pass nine billion by 2075. This image depicts the Earth at night as observed by the Visible Infrared Imaging Radiometer Suite's (VIIRS) "day-night band" onboard the Suomi National Polar-orbiting Partnership (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 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. More than seven 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. Looking broadly, the causes of biodiversity loss include the conversion of natural habitats, increasing resources extraction, pollution, invasive species, and a changing climate.

**Global Living Planet Index**  
(WWF/ZSL, 2012)



Credit: World Wildlife Fund, Zoological Society of London



Photo credit: Jane Sawyer

[Above] Desert ecosystems are home to a surprisingly wide variety of plants and animals that have adapted to the region's dry climate.

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

**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.

[Left] The Global Living Planet Index—a measure of the status of vertebrate populations—shows a decline around 30% from 1970 to 2008, based on nearly 8000 populations of more than 2500 species of birds, mammals, amphibians, reptiles, and fish. The white line represents the index, while the shaded blue area represents the confidence interval.



Credit: NASA's Earth Observatory

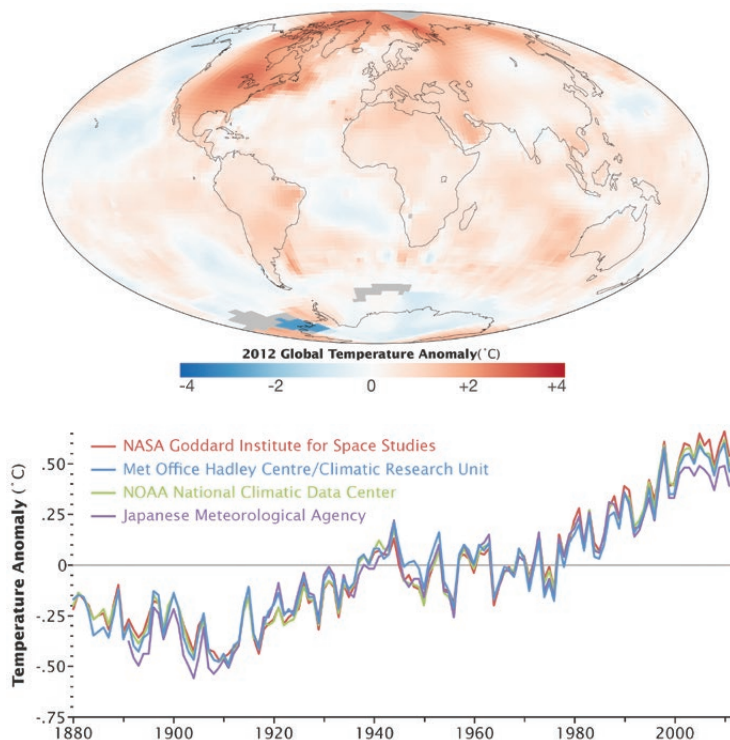
[Above] Large-scale forest removal, or deforestation, results in the degradation of environments, habitat loss, and the extinction of species. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured these images of deforestation in the state of Rondônia in western Brazil on July 30, 2000 [top] and August 2, 2010 [bottom]. Intact forest is deep green, while cleared areas are tan (bare ground) or light green (crops, pastures). Rondônia has become one of the most deforested parts of the Amazon.

**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.

## Observing Environmental Changes that Impact Biodiversity

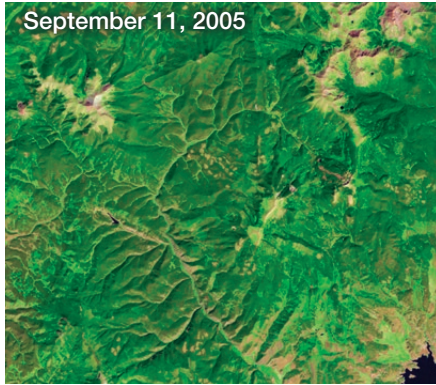
The vantage point of space provides a unique perspective to observe Earth's surfaces at local, regional, and global scales, as well as over time. For decades, satellite and airborne remote sensing instruments have been observing environmental changes that impact biodiversity including: increases in deforestation, increases in urban growth, 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. Scientists use this information to understand patterns of biodiversity, how biodiversity is changing, the drivers of the changes, and to predict the impacts of environmental changes on biodiversity in the future.



Credits: NASA's Earth Observatory

[Above] In recent decades, average global temperatures have been rising. This map shows temperature anomalies by region in 2012. Reds and blues show how much warmer or cooler each area was in 2012 compared to an averaged base period from 1951 to 1980. The graph shows yearly temperature anomalies from 1880 to 2011 as recorded by four institutions that tally temperature data from stations around the world. Though there are minor variations from year to year, the general trend, and annual variations, is the same in all four records. All show rapid warming in the past few decades, and all show the last decade as the warmest. Overall, the average global temperature has increased 0.8 °C (1.4 °F) since 1880.



Credit: U.S. Geological Survey and NASA's Earth Observatory

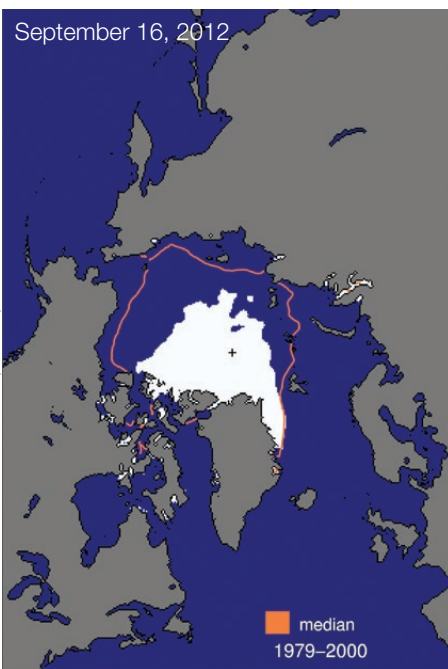
[Above] Warmer winters and drier summers across the Rocky Mountains have led to an increase in mountain pine beetle outbreaks. This pair of images from the Landsat-5 satellite reveals beetle damage in Rocky Mountain National Park in Colorado. In 2005 [left] healthy forests appeared bright green. Just 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.



Photo credit: Ron Long, Simon Fraser University

[Above] Photograph of a mountain pine beetle.

**BIO FACT:** Research led by NASA-funded scientists indicates that tree species in the Pacific Northwestern United States appear less adapted to recent changes in climate in parts of their natural ranges. The models they use, which were able to reproduce the historical ranges of 20 tree species with 80% accuracy, suggest that tree species in both the United States as well as Canada may be starting to retreat in some places and expand into others where climatic conditions are more suitable. Projected future climate conditions may cause even greater range shifts. Credit: Richard Waring, Oregon State University



Credit: National Snow and Ice Data Center, Boulder, Colorado

[Left] Satellite and other measurements have revealed that the Arctic is warming at rates faster than anywhere else on Earth, causing dramatic reductions in minimum sea-ice extent and changes in the extent and types of vegetation found in the Arctic, which impact Arctic ecosystems and biodiversity. On September 16, 2012, sea ice covering the Arctic Ocean declined to the lowest extent in the satellite record, which began in 1979. In this image, sea ice extent appears white, while the orange line shows the 1979 to 2000 median extent for that day.

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



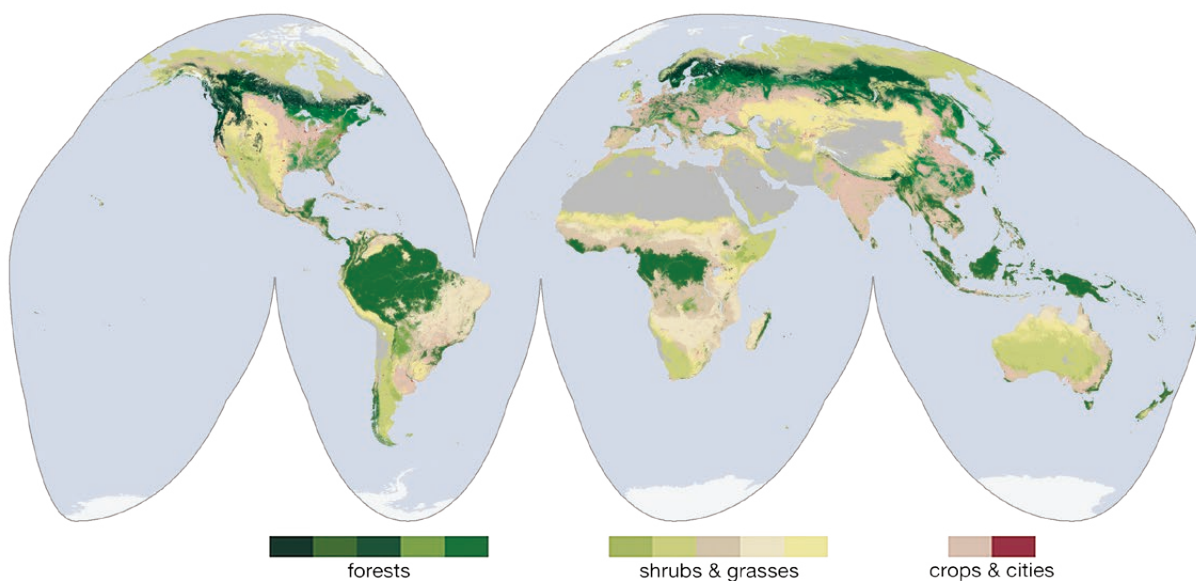
Credit: NASA

## 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.

[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 February 2013, Landsat 8 (pictured here) continues the legacy of Landsat's invaluable data archive and will provide new perspectives of our planet for years to come. Landsat imagery is available to all users free of charge.*

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.

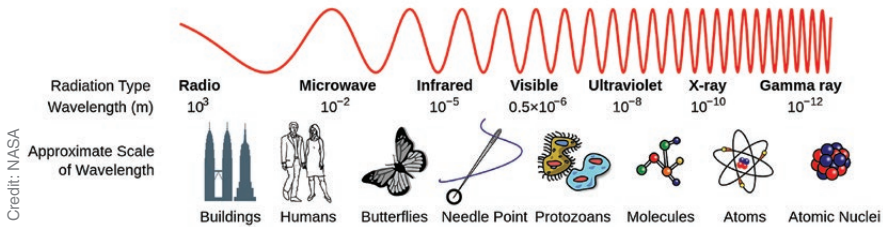


Credit: NASA

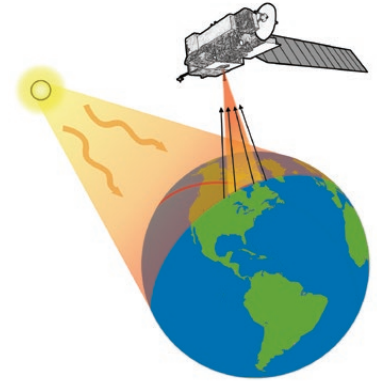
[Above] *Created with data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instrument onboard the Terra and Aqua satellites, this map shows global land cover classification types. Data from MODIS are widely used to study patterns and changes in land cover as well as changes in vegetation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







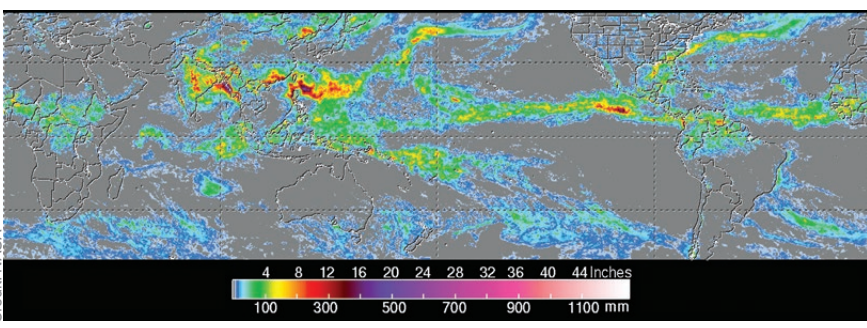
Credit: NASA



Credit: NASA

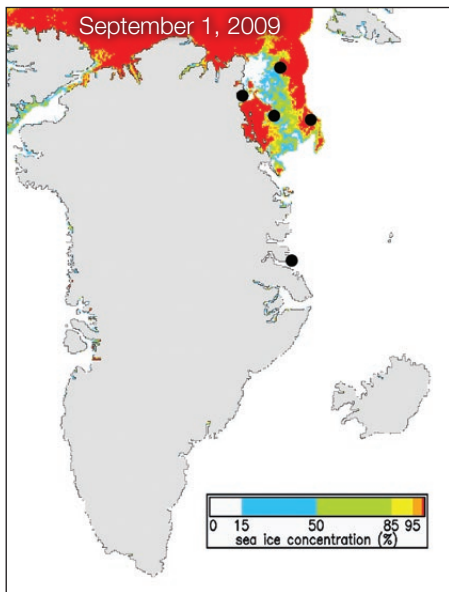
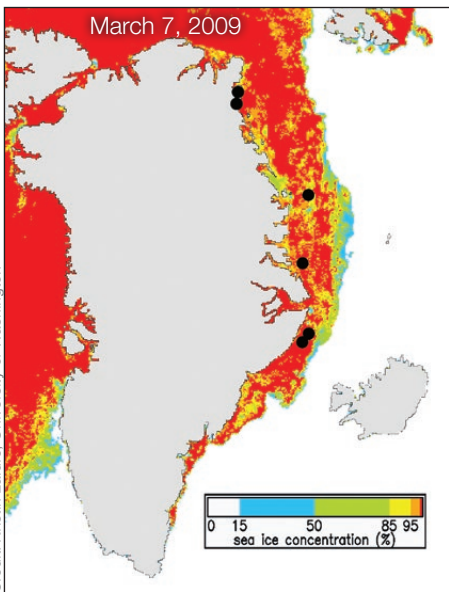
[Above] The electromagnetic spectrum is the range of traveling waves of energy that include gamma and x-rays, ultraviolet light, infrared radiation, microwaves, and radio waves. Human eyes are adapted to see a narrow band of this spectrum called visible light. Soils, different plant types, water, bare 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.

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



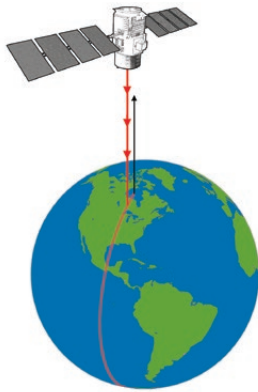
Credit: NASA

[Left] This image shows rainfall accumulations derived from Tropical Rainfall Measuring Mission (TRMM) data from April 17 to April 24, 2013. Scientists use remotely sensed environmental parameters such as precipitation measurements to study species distributions and other components of biodiversity.



Credit: Kristin Laidre, University of Washington

[Above] 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.



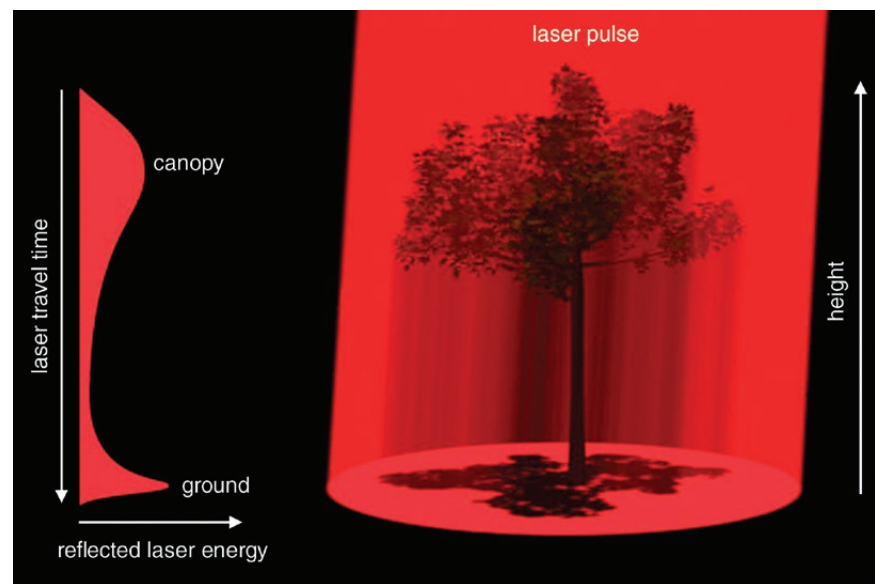
Credit: NASA

[Above] 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.

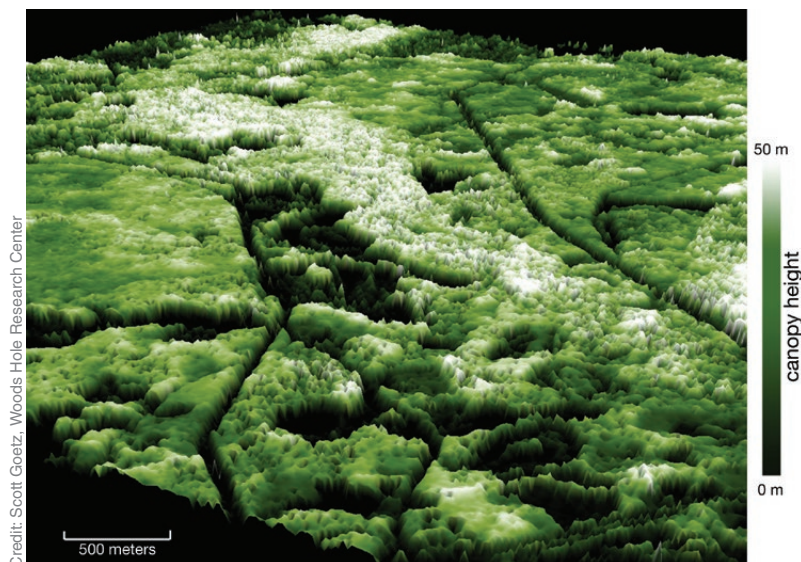
By combining satellite and airborne measurements from both passive and active sensors with ground-based measurements, scientists can estimate the distribution of and changes in biodiversity at all levels and on all scales.

[Right] 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 aboveground biomass over large areas.



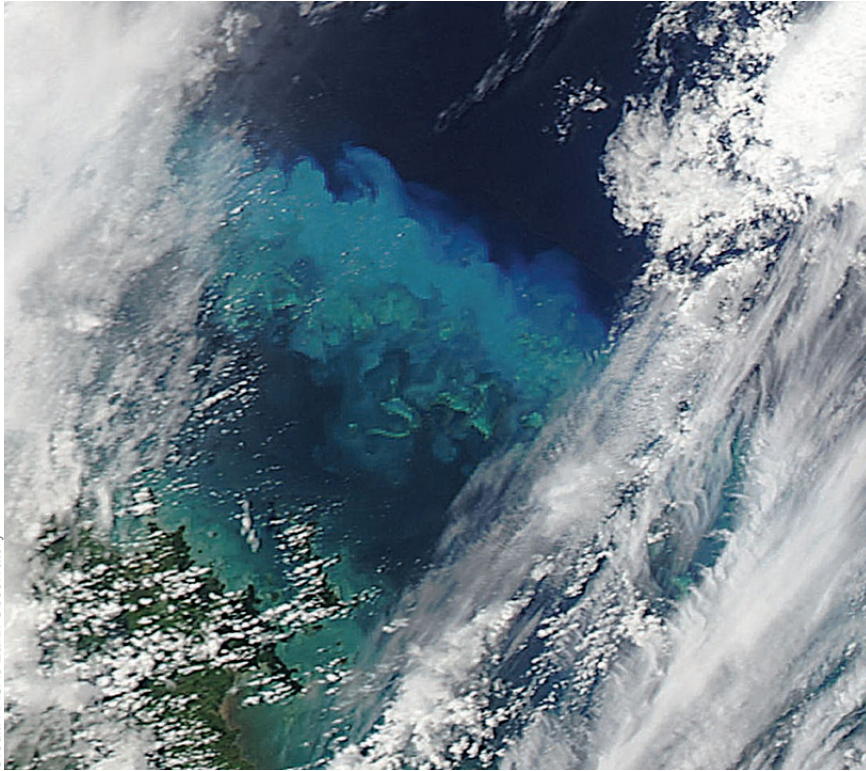
Credit: NASA

[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





[Left] In this image taken by the passive MODIS sensor onboard NASA's Aqua satellite on February 4, 2011, the normally clear, shallow water of the Great Barrier Reef was clouded with sediment brought to the surface by Cyclone Yasi. Light reflects off the bright-colored sediment, turning the ocean electric blue. Active remote sensors such as lidar instruments can be used to measure suspended sediment concentrations, which allow scientists to make predictions about how sediment will affect the life on the reef.

---

**BIO FACT:** Future satellite missions such as the Global Precipitation Measurement (GPM) Core Observatory and Soil Moisture Active Passive (SMAP) will 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.

---

### HyspIRI to Study the World's Ecosystems

NASA is studying concepts for a Hyperspectral Infrared Imager (HyspIRI) satellite mission that will observe the world's ecosystems and also provide critical information on extreme events such as volcanoes, wildfires, and drought. The instruments will be capable of distinguishing vegetation type and parameters relevant to vegetation condition and thus will provide a benchmark on the state of the world's ecosystems and measure seasonal changes in these systems. HyspIRI will have two instruments: a visible-to-shortwave-infrared (VSWIR) imaging spectrometer (sometimes called a hyperspectral sensor) and a multispectral imager that covers sections of the mid- and thermal-IR (TIR) portion of the electromagnetic spectrum with 8 channels. Both instruments have a ground sampling spatial resolution of 60 meters (~197 feet).



[Above] Artist's rendition of the HyspIRI spacecraft.



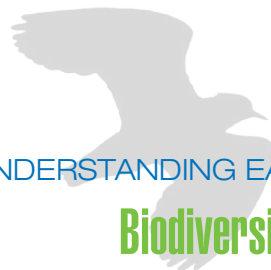
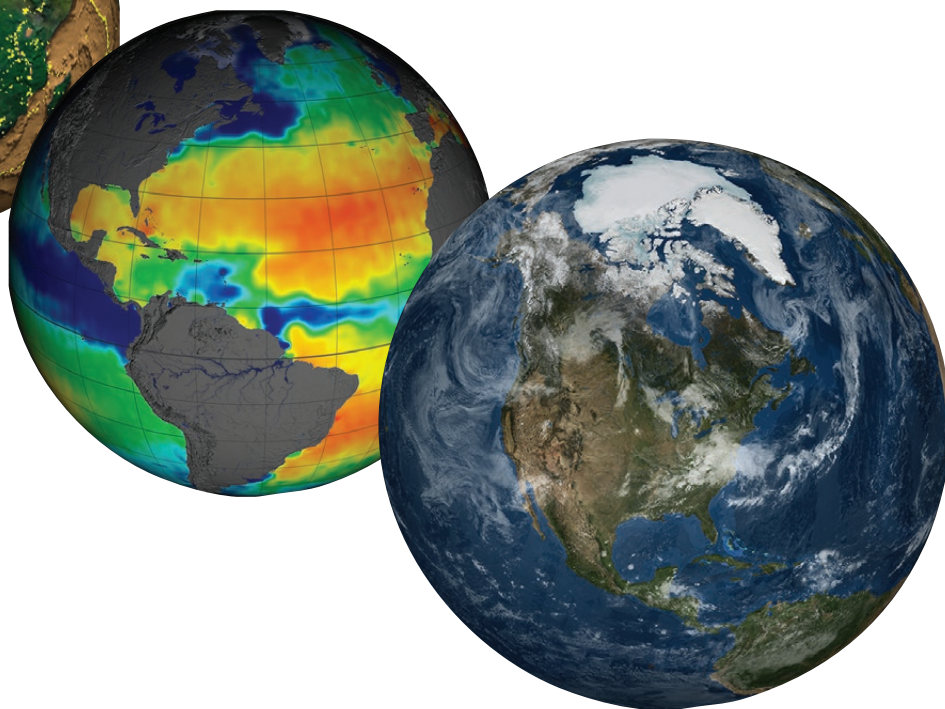
Photo credits: ribbla (morgueFile.com), D. F. McLean, Anthony Kelly, Rene Cunningham

[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*.

[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, both now and in the future.*



Ecological forecasting 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 Forecasting 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.

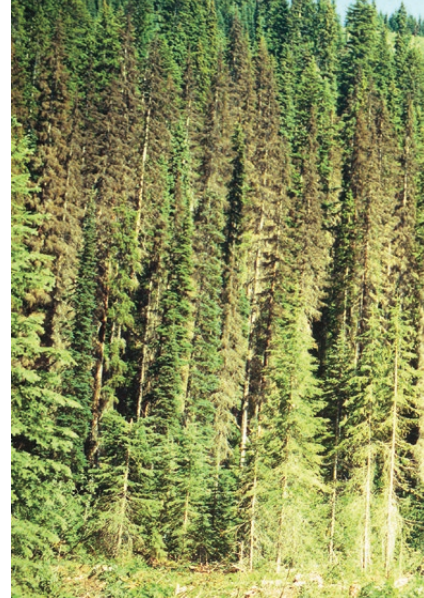
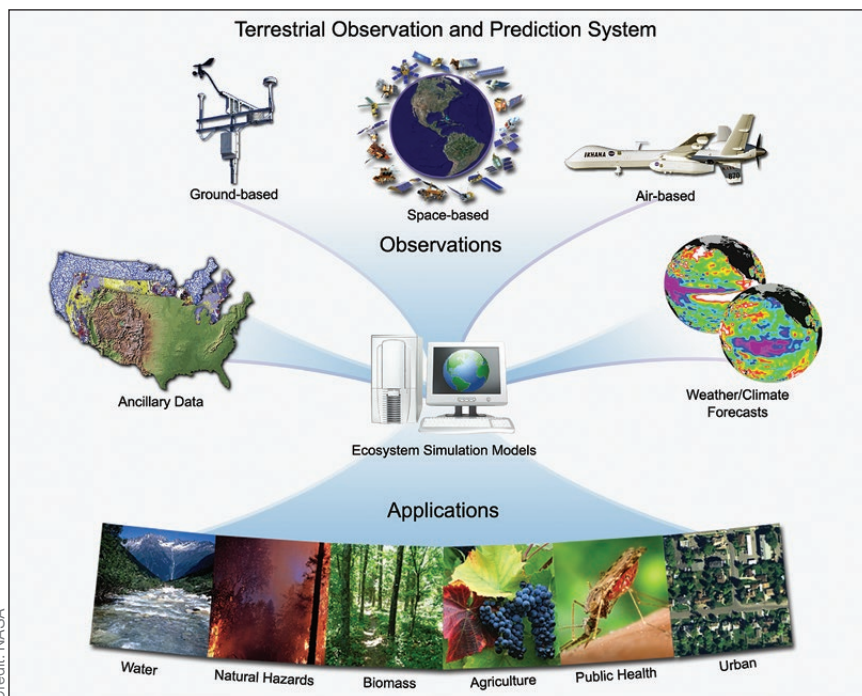


Photo credit: U.S. Dept. of Agriculture Forest Service



Photo credit: U. S. Dept. of Agriculture Forest Service

[Left] Ecological forecasts allow forest managers to make informed environmental decisions that protect biodiversity.



Credit: NASA

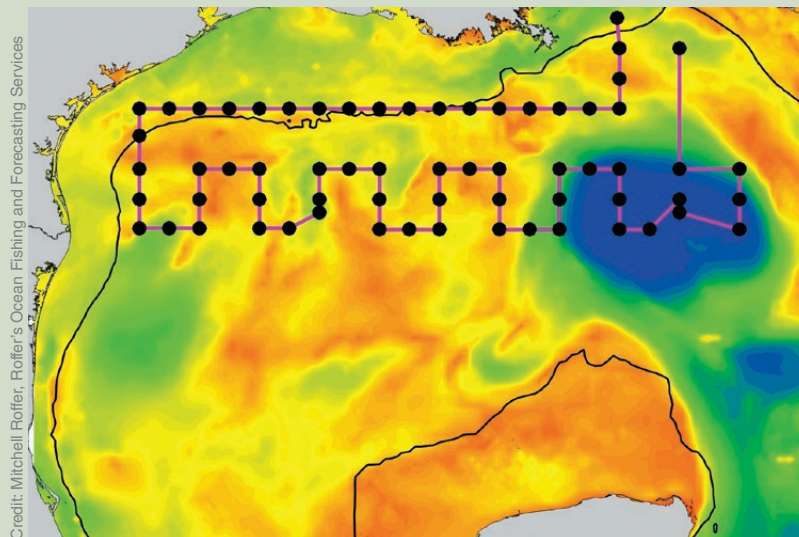
[Left] Scientists at NASA are using the Terrestrial Observation and Prediction System (TOPS) to develop nowcasts (short-term predictions) and forecasts of ecosystem conditions for use in a range of applications. TOPS is a data and modeling software system designed to seamlessly integrate data from satellite, aircraft, and ground-based sensors with weather, climate, and applications models. These models operate at a variety of spatial and temporal scales, ranging from individual stream reaches to global monthly assessments of vegetation productivity.

## Improving Atlantic Bluefin Tuna Larval Surveys

The Atlantic bluefin tuna is one of the largest and most valuable fish in the sea; however, their populations have been declining. To provide fishery management authorities with information about tuna populations and their trends, scientists used sea surface temperature and ocean color data (i.e., chlorophyll a) from NASA's Terra and Aqua satellites, sea surface height data from the Jason satellite, and *in situ* measurements of temperature, salinity, bottom depth, and other factors to develop a habitat classification model of Atlantic bluefin tuna larval occurrence in the Gulf of Mexico. Authorities used the model and real-time satellite observations to forecast larval occurrence, which improved the efficiency of ship-based larval surveys. The techniques and the habitat classification model have been successfully transferred to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, which now routinely incorporate satellite observations into the larval survey and population assessment process, leading to more accurate stock assessments used in the international management of this species.



Photo credit: NOAA



Credit: Mitchell Roffer, Roffer's Ocean Fishing and Forecasting Services

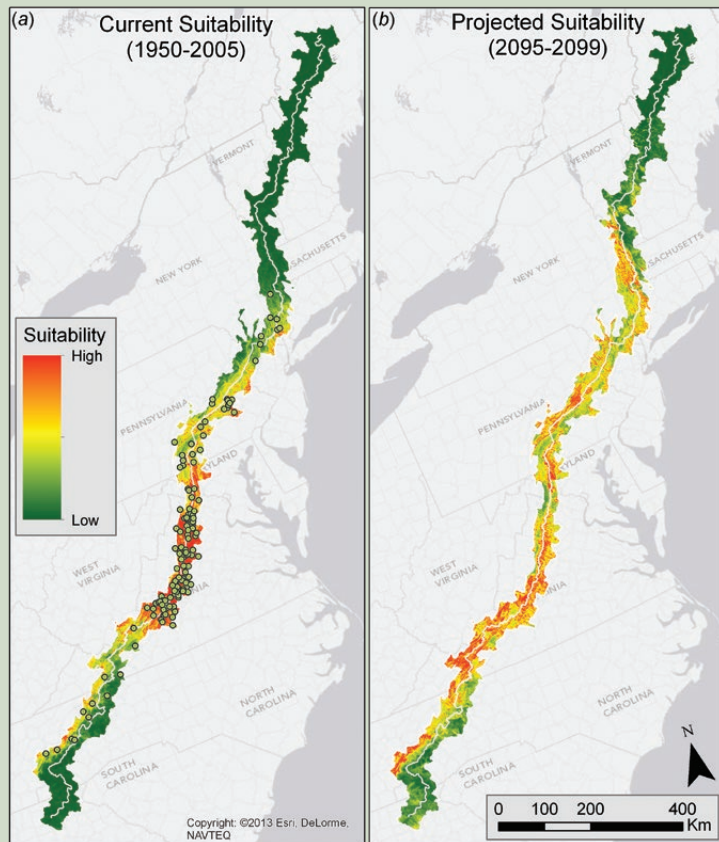
[Above] The project team applied satellite infrared and ocean color data from May 1–7, 2011, to derive a larvae habitat model. The model helped explain the variation in catches at the fixed sampling sites (black dots) in the Gulf of Mexico. Warm colors (orange-red) depict areas with high probability of finding larvae, while cool colors (blue and green) depict low-probability areas.



## Earth Observations Help Predict the Impacts of Climate Change on the Appalachian Trail

The National Appalachian Scenic Trail stretches approximately 3500 kilometers (2175 miles) north to south across the United States from Maine to Georgia. In partnership with the National Park Service, United States Forest Service, Appalachian Trail Conservancy, and the United States Geological Survey, NASA-funded researchers have developed an online decision support system that uses the Terrestrial Observation and Prediction System (TOPS) framework for monitoring, reporting, and forecasting the ecological conditions of the Appalachian Trail region—including projecting the impact of climate and land-use changes on the trail. An example is demonstrated below, which shows the current and projected habitat suitability and distribution of an invasive species from China and Taiwan called *Ailanthus altissima*—commonly referred to as the tree-of-heaven. The tree-of-heaven continues to spread along the Appalachian Trail and adversely affects native vegetation. Land managers use maps like these to understand where invasive species may occur under current as well as future climate conditions, which informs their planning and management practices.

[Right] The map on the left shows modeled habitat suitability for tree-of-heaven based on climate data from 1950 to 2005. The dots indicate where the tree-of-heaven is currently found along the trail from United States Forest Service field surveys. The map on the right shows projected habitat suitability data based on a climate projection from 2095 to 2099 from the TOPS framework. Warm colors (orange shades) indicate areas that are more suitable for tree-of-heaven, while cool colors (green shades) indicate areas that are less suitable.



Credit: Yeqiao Wang, The University of Rhode Island

Resources	Contacts
NASA Biodiversity Program <a href="http://cce.nasa.gov/cce/biodiversity">cce.nasa.gov/cce/biodiversity</a>	Woody Turner Biological Diversity Program Manager Ecological Forecasting Program Manager <a href="mailto:woody.turner@nasa.gov">woody.turner@nasa.gov</a>
NASA Applied Sciences Program <a href="http://appliedsciences.nasa.gov">appliedsciences.nasa.gov</a>	
NASA's Earth Observing System Data and Information System <a href="http://earthdata.nasa.gov">earthdata.nasa.gov</a>	Allison Leidner Scientist <a href="mailto:allison.k.leidner@nasa.gov">allison.k.leidner@nasa.gov</a>



Collect all of the **Understanding Earth** books

**The Journey of Dust**

**Biomass Burning**

**The Icy Arctic**

**Biodiversity & Ecological Forecasting**

**Our Ocean**

**What's Up with Precipitation**

National Aeronautics and Space Administration  
Goddard Space Flight Center  
Greenbelt, Maryland

[www.nasa.gov](http://www.nasa.gov)