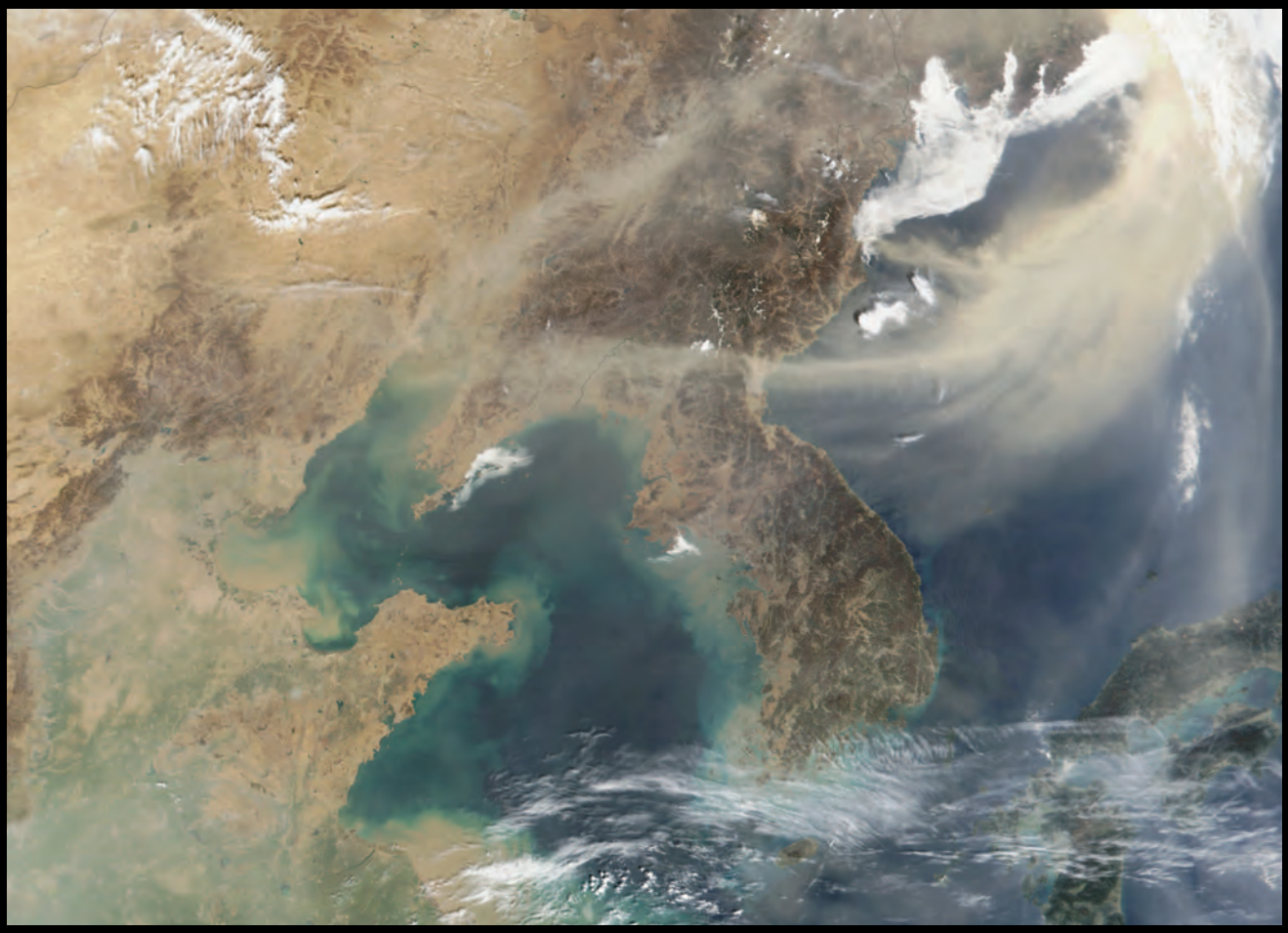
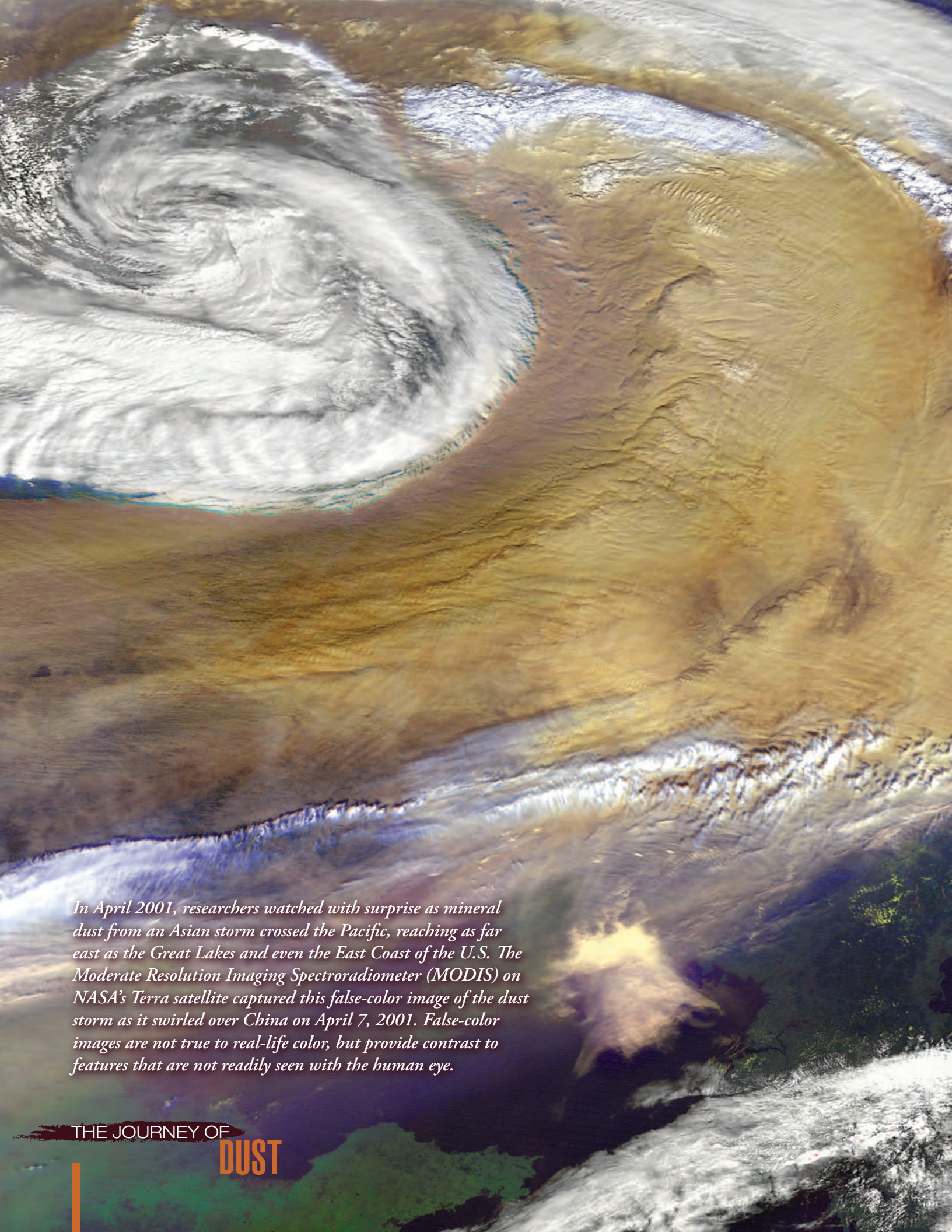
National Aeronautics and Space Administration

UNDERSTANDING EARTH

The Journey of Dust



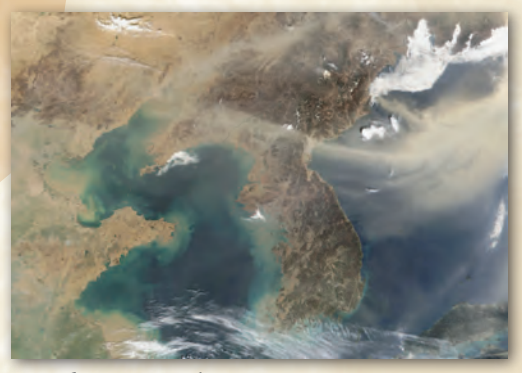


In April 2001, researchers watched with surprise as mineral dust from an Asian storm crossed the Pacific, reaching as far east as the Great Lakes and even the East Coast of the U.S. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured this false-color image of the dust storm as it swirled over China on April 7, 2001. False-color images are not true to real-life color, but provide contrast to features that are not readily seen with the human eye.

THE JOURNEY OF

DUST

UNDERSTANDING EARTH:
The Journey of Dust



On the cover: The MODIS instrument flying on NASA's Terra satellite captured this true to real-life image of a spring dust storm blowing eastward from China on April 1, 2002.

A NASA scientist made this footprint in the dust, not on the moon, but in the Great Gobi Desert surrounding the Dunhuang Oasis, China, during the ACE-Asia field experiment.*

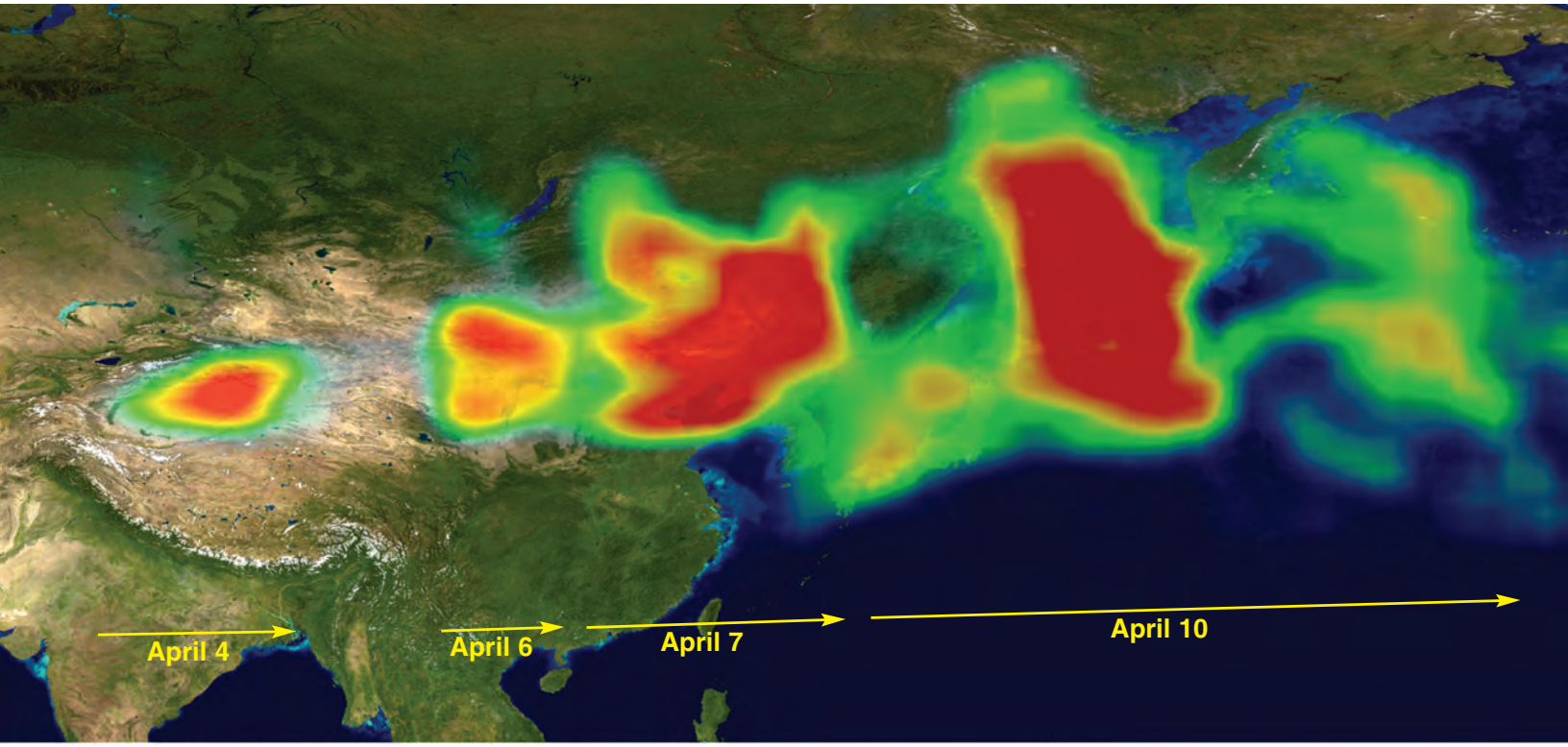
WHAT IS DUST?

On Earth, dust forms when rocks are broken down into sand and smaller particles. These particles, called ***mineral dust***, can be blown by the wind and suspended in the atmosphere. The deserts on Earth are huge sources of dust, with the Sahara and Gobi Deserts as the main sources. Desert dust is one of many types of tiny particles found in our atmosphere called ***aerosols***.

THE "PERFECT DUST STORM"

Every spring, dust from deserts in Mongolia and China invades heavily populated cities in Eastern Asia, such as Beijing. These wind-whipped dust storms darken the sky and blanket streets, homes, and cars.

In April 2001, the "Perfect Dust Storm" formed as winds from Siberia pushed millions of tons of dust from the Gobi and Taklimakan Deserts



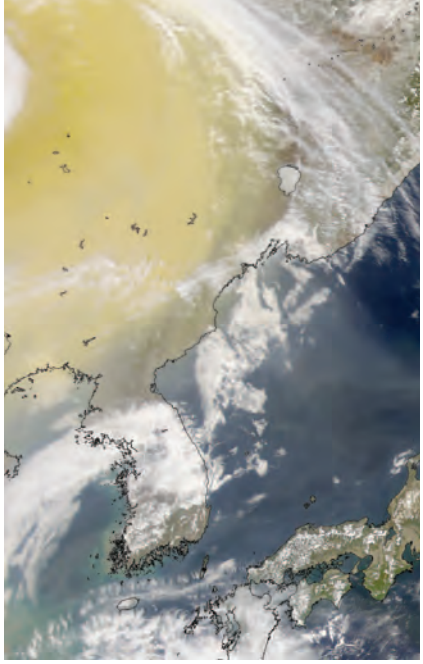
This image shows aerosol amount, as measured by the TOMS instrument on the Earth Probe satellite. It dramatically illustrates how a huge dust storm that formed in China around April 4, 2001 moved across the Pacific Ocean and North America, some of it reaching the Atlantic Ocean by April 16. Dust amount is superimposed on a true-color image of the Asian land surface from MODIS/Terra, composited with topographic data from the U.S. Geological Survey (USGS). The arrows point out the size and location of the dust plume on the dates indicated. Red areas highlight the densest parts of the dust cloud on each day. Yellows and greens show moderately high amounts.

over China, Korea, and Japan. After the storm dumped dust on Eastern Asia, air currents carried it across the Pacific, and some dust from the cloud reached North America about a week later.

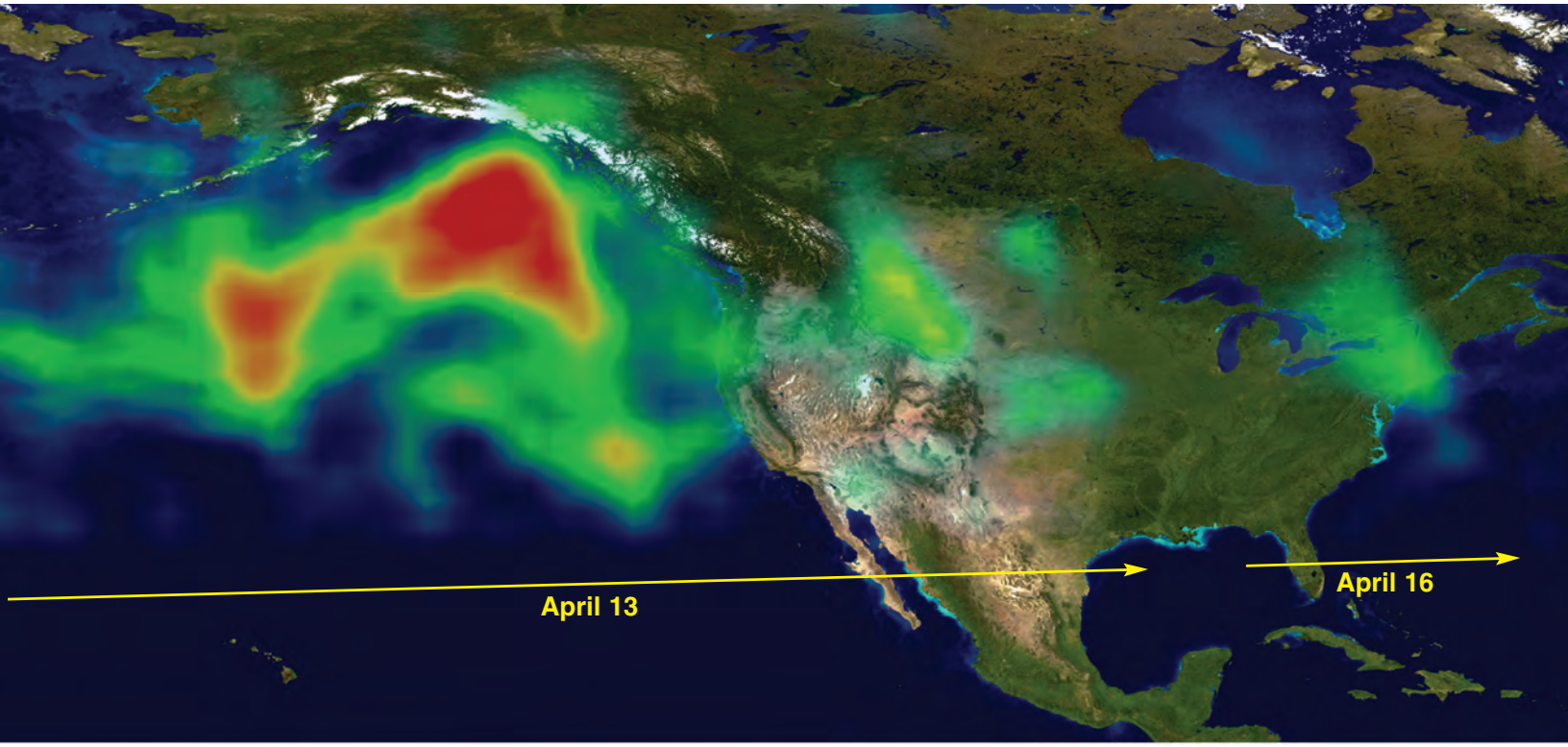
TRACKING THE STORM

To see the whole outline of any large dust cloud, you need to look down from space. Scientists use NASA instruments on satellites flying above Earth to detect tiny dust particles in the air. Among other satellite sensors, the Total Ozone Mapping Spectrometer (TOMS) instrument on the Earth Probe satellite, the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on the Orbview-2 satellite, and the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on the Terra satellite, equipped with wide spatial coverage, all tracked the path of the "Perfect Dust Storm".

Satellite instruments tracked this dust cloud for more than two weeks, until it thinned to the point of disappearing from images on April 24. By then, it had traveled halfway across the Atlantic Ocean on its way to England!



On April 7, 2001, the SeaWiFS instrument on the Orbview-2 satellite observed a giant yellow dust cloud that covered most of China.



DUST FACT: Desert dust contains common crustal minerals, such as silica, calcium carbonate, and iron oxides.

* In the spring of 2001, NASA scientists took part in the Aerosol Characterization Experiments (ACE)-Asia—the fourth in a series of experiments designed to increase our understanding of how atmospheric aerosol particles affect Earth's climate system. For more information about ACE-Asia, please visit: *http://saga.pmel.noaa.gov/Field/aceasia/*.

Photo credit: nperiksson

Because there are large deserts upwind of Beijing, China, it is common for dust clouds to enter the city.

EFFECTS OF THE STORM

The "Perfect Dust Storm" caused many problems in Eastern Asia. The dust reduced visibility, making travel difficult. People were advised to stay indoors. Hospitals filled with people suffering from asthma and other breathing problems. For people who are already sick, exposure to a dust storm can be deadly.

The sky was so dark from the dust that it looked like nighttime. Businesses, schools, and airports all closed. As the dust cloud passed through the cities, it mixed with pollutants in the air, such as carbon monoxide, soot, mercury, and sulfur dioxide given off by factories, power plants, and vehicles. The cloud also picked up bacteria, fungi, and pesticides as well. These pollutants were then slowly deposited as the dust cloud made its way eastward over cropland, other cities, and the ocean.

By the time the "Perfect Dust Storm" reached North America, it only showed up in the sky as a white haze. A fine layer of dust fell on some cities but no major health or traffic problems were reported.

WHAT CAUSED THE STORM?

DUST FACT: Dust storms cause billions of dollars in damage each year. Human health, livestock, crops, and fish stocks can all be adversely affected. A dust storm in May 1993 killed 85 people in Western China.

While wind is the natural cause of dust storms, human activities might make dust storms more frequent and severe in some places. Poor farming practices and over-grazing by livestock can reduce protective land cover and dry out the surface—a process called ***desertification***. When grasses and other land cover are lost, it is easier for dust to be swept up by the wind. Over time, deserts such as the Gobi can slowly advance due to desertification. During droughts, the low rainfall can accelerate this process.

Photo credit: romainguy

As human and animal populations grow in China and Eastern Asia, overgrazing increases, as well as land-clearing for agriculture and development.

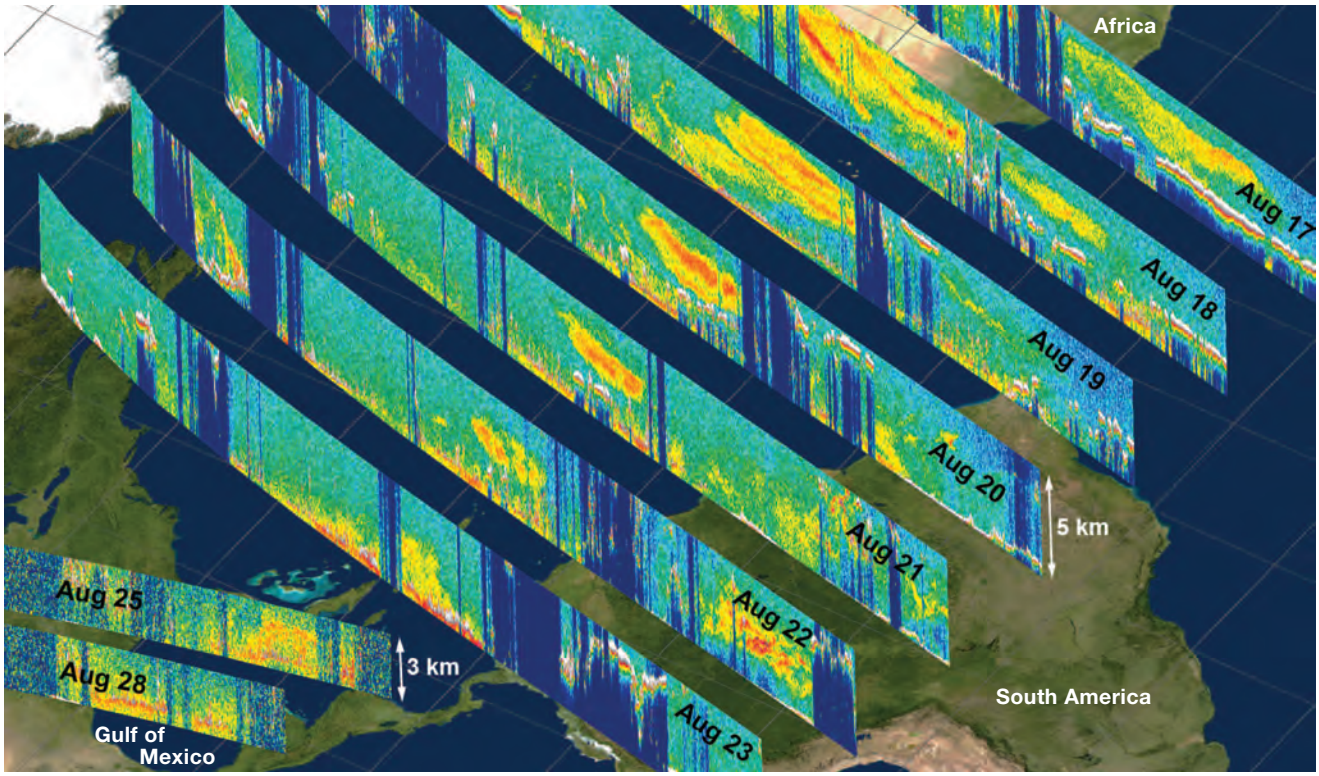
CHANGING CLIMATE AND ECOSYSTEMS

Desert dust, wildfire smoke, and sea salt particles are naturally produced, whereas human activity, such as manufacturing, farming, and transportation, also generate aerosols. Most of these airborne particles reflect enough sunlight back to space to have a net cooling effect on the planet, which is often referred to as a ***direct radiative effect*** on climate. In addition, aerosols play a role in cloud formation, acting as "seeds" around which water molecules accumulate into cloud droplets. As such, the amount and type of particles in the atmosphere can affect cloud properties, altering their brightness and possibly also their lifetime, and producing a so-called ***indirect effect*** on climate as well.

Desert dust impacts living things in ***ecosystems*** in a variety of ways. If cloud cover changes as a result of dust, then the amount of rainfall over a region may change, and the ecosystem may change in response. A fungus contained in African dust transported over the ocean may be the cause of damage to Caribbean sea corals. Desert dust contains iron. Under some circumstances, when transported dust settles on remote, iron-poor ocean surface waters, it can release iron, fertilizing the population of tiny floating plants called ***phytoplankton***. Phytoplankton are an important food source for fish and whales. Rainforests get vital nutrients from dust and the trees in them play a key role in regulating climate.

DUST FACT: Sunlight scattered by dust enhances the oranges and reds you see in a colorful sunset.

Photo credit: Wonker



In this image, vertical slices through the atmosphere show both dust from North Africa and smoke from Central Africa in bright orange and yellow, traveling westward across the Atlantic Ocean between August 17–28, 2006. The long slices were obtained by the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument on board the CALIPSO spacecraft, and the two shorter slices over the Gulf of Mexico were acquired by a NASA High-Spectral-Resolution Lidar (HSRL) on board an aircraft. Dark blue striping marks locations where clouds at high altitudes prevented CALIPSO's beam from probing the atmosphere below. One kilometer (km) equals 0.62 miles.

DUST STORM DISASTERS

- In the 1930s, the Great Plains of the U.S. became known as the "Dust Bowl" because of prolonged drought and accompanying strong dust storms that blackened the sky and forced families to abandon their farms. In his famous novel *The Grapes of Wrath*, John Steinbeck captured the hardships of the people who were displaced.
- The Melbourne dust storm in Australia in 1983 uprooted trees and unroofed 50 houses.
- The 2007 dust storm in Amarillo, Texas caused car accidents, property damage, and crippled the Dallas Fort Worth airport.

Photo credit: NOAA George E. Marsh Album.

A dust storm approaches Stratford, Texas on April 18, 1935.

March 20, 2002

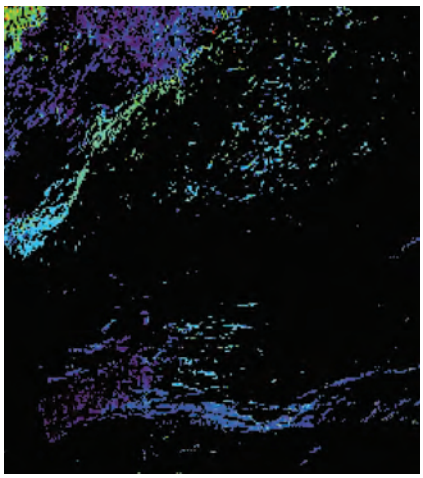
Photo credit: NotLiz

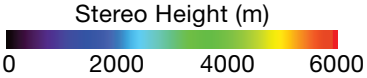
In March 2002, a large plume of dust blew south and east from the Mongolian desert. In Beijing, China [left], skies turned yellow from the particles in the air. Chinese media reported that the dust storm affected 100 million people and was the worst in a decade. On March 23 [below, left], NASA's Multi-angle Imaging SpectroRadiometer (MISR) flying onboard the Terra satellite observed relatively clear skies over China's Liaodong region. Sixteen days later, when the Terra satellite passed over the same area [below, middle], another dust storm had developed that obscured most of the land surface. MISR can distinguish non-spherical dust from spherical particles such as smoke, and uses stereo viewing to map the heights of dust plumes [below, right]. Dusty regions appear in purples and blues, indicating heights of 1 to 2 kilometers (about 0.6 to 1.2 miles), whereas the more elevated water cloud in the upper left of this scene is shown in greens and yellows.

March 23, 2002

April 8, 2002

April 8, 2002





In September of 2009, an unwelcome visitor came to Eastern Australia. Winds blew orange dust from the dry interior of the continent, called the Outback, into cities in the territories of New South Wales and Queensland. The storm, the worst in 70 years, first reached the capital Canberra on September 22 before it hit Sydney and Brisbane on September 23.

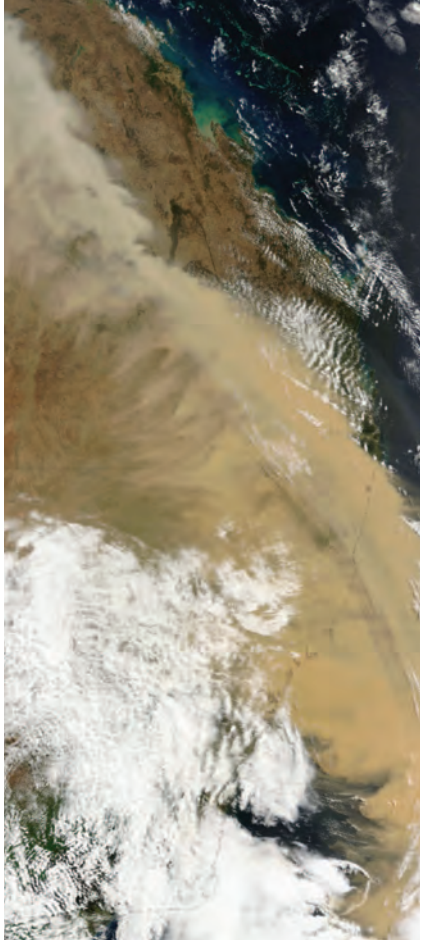
Residents awoke to a strangely orange sky that many described as a scene in a disaster movie. The haze descended over everything, disrupting airports, schools, and traffic. People with health problems were advised to stay indoors and commuters used masks and handkerchiefs to cover their faces as they made their way to work. Healthy people who breathed the dust had scratchy throats and a metallic taste in their mouths. The dust set off fire alarms and harmed wildlife; people even reported seeing birds drop out of the sky.

The storm began when strong winds sent soil from Australia's dry farm fields into the air and transported it hundreds of miles east. Due to a multi-year drought, the worst on record, crops were not planted in these fields, leaving the parched soil exposed. The MODIS instrument aboard NASA's Terra satellite showed the dust plume as it traveled from farm fields to Eastern Australia. From space, the dust appeared so thick that the land beneath it could not seen.

The wind carried the dust further east and out to sea, leaving the cities with a huge mess. Queensland officials lifted the restrictions on water usage that had been placed due to the drought so residents could start the cleanup. Environmental scientists are concerned that these kinds of storms will become more common unless more vegetation is planted and maintained.

Photo credit: El Fotopakismo.

In this photo of the Eleanor Schonell bridge, taken on September 23, 2009, orange dust filled the sky over the Brisbane River, University of Queensland.



A wall of dust stretched from Northern Queensland to the southern tip of Eastern Australia on the morning of September 23, 2009, when the MODIS instrument aboard the Terra satellite captured this image.

DUST FACT: Dust storms on Mars are bigger and stronger than those on Earth. In 2007, an Australia-sized dust storm blocked out the sun, forcing the solar-powered *Spirit* and *Opportunity* rovers on the Mars surface to take "naps" to save energy.

Photo credit: Thomas Roche

"The Green Wall of China", Gobi Desert

Photo credit: Bert van Dijk

In an effort to prevent desertification, grasses are planted in a checkerboard pattern to help hold the sand and soil in place.

DUST FACT: Camels are especially suited for dust storms; their long eyelashes and ear hairs and the ability to seal their nostrils protect them from blowing sand.

Photo credit: indigoprime

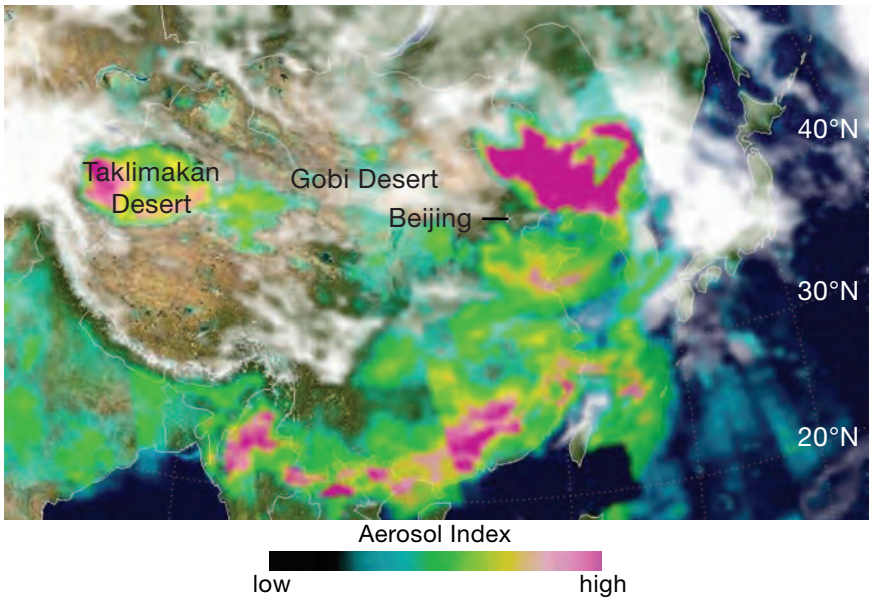
TAMING THE STORM

Asian dust storms have been occurring for centuries. However, their frequency has increased so much in the past 50 years that efforts are being made to prevent and control them.

One way to fight dust storms is with plants. Grasses and trees help keep the sand and soil in place. "The Green Wall of China" is a project to plant trees—2,800 miles of them—in Northwest China near the edge of the Gobi Desert. Inside the belt of trees, plants like wheat and rice are planted in a checkerboard pattern. The project, planned to be completed in 2074, has slowed due to high costs. Also, some of the trees planted have died.

Another dust-control practice is placing wire fencing in areas to keep livestock from overgrazing. Plastic mulch and chemicals, such as oil waste, can be effective at keeping sand in place, but damage the environment in other ways. Further ideas for reducing desertification include paying farmers to reduce livestock numbers and raising prices of water so the resource will be conserved.

The solution to managing dust storms isn't simple and won't happen quickly. Computer models are used in Eastern Asia today to predict when dust storms will occur and how strong they will be. NASA satellites continue to be ready to track the next "Perfect Dust Storm", giving us important information about how dust storms impact life on Earth.



The Ozone Monitoring Instrument (OMI) flying onboard the Aura satellite has the unique ability to measure the thickness of aerosols above clouds. This image, captured by OMI in 2007, shows springtime aerosols as they travel over Eastern Asia and thin out over the Western Pacific. Red areas are where aerosols are generally the thickest. The source of aerosols in the north is probably dust, while aerosols south of 30° North latitude are likely due to smoke from biomass burning.

CAUGHT IN A DUST STORM?

Dust storms can happen quickly but warning systems are in place to help you prepare. Meteorologists recognize conditions when dust storms are most likely to occur and can often predict an oncoming storm. In threatening weather, tune into local TV or radio stations for dust storm warnings.

During a dust storm, stay indoors if you can, with windows and doors closed.

If you must go outside, avoid vigorous exercise and spend as little time as possible outdoors.

Special masks, usually available at hardware stores, are better at protecting you from dust than handkerchiefs or bandannas. A mask can make it harder to breathe normally so if you have a pre-existing heart or lung condition ask your doctor if you should wear one.

Dust can quickly reduce visibility, causing accidents that may involve chain collisions and create massive pileups.

If you are driving and a dust storm occurs, you should pull to the side of the road and keep your headlights off. The National Weather Service reports some drivers navigating the road by using the taillights on the car in front of them have accidentally veered off and collided with vehicles that had pulled off the roadway during the storm and parked.

If you can't pull off the roadway, proceed at a speed suitable for visibility, turn on lights, and sound horn occasionally until you can find a safe place to pull off.

This information and other dust storm safety tips are available from the National Weather Service at *www.nws.noaa.gov/om/brochures/duststrm.htm* and the Victoria, Australia Department of Health at *www.health.vic.gov.au/environment/emergency_mgmnt/dust_storms.htm.*

NASA Resources:

eos.nasa.gov
earthobservatory.nasa.gov
visibleearth.nasa.gov
aqua.nasa.gov
aura.nasa.gov
www-calipso.larc.nasa.gov
oceancolor.gsfc.nasa.gov/SeaWiFS/
terra.nasa.gov

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

www.nasa.gov

NP-2010-4-134-GSFC