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NARRATOR: Our planet: Earth—you may think you know it well, but a startling new picture is emerging of a world shaped by forces more dynamic and intertwined than we ever imagined, raising possibilities that defy common sense.

How can sandstorms in the Sahara Desert transform the Amazon rainforest, over 5,000 miles away? In the frigid ocean beneath Antarctica, how can a vast undersea waterfall, 500 times bigger than Niagara Falls, lead to a gigantic feeding frenzy near the equator? And how can warm water, streaming past the coast of Africa, trigger a weather catastrophe, half a world away, in the southern United States?

Scientists have begun to find surprising answers to these and other profound questions, thanks to a network of satellites, orbiting high above the earth. Ever watchful, their senses extend far beyond what our eyes can see.

EMILY SHUCKBURGH (British Antarctic Survey): It's really the last **bastion** of human discovery. We're discovering new things every day.

NARRATOR: What are these hidden forces that rule our world? How are the oceans, the continents, the atmosphere and even the sun bound together, and how do they affect all living things? For the first time, we can understand how earth, fire, wind and water join together to create the dynamic environments that shaped life in all its forms.

WALEED ABDALATI (NASA Chief Scientist): Their interaction is what has created the environment, the diversity, the kind of life we see on Earth today.

NARRATOR: With astonishing images created from a wealth of new information from satellites, this is our planet, as never seen before: Earth from Space, right now, on NOVA.

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Since humans first ventured into space, some of the greatest gifts of exploration have been the new views of our home. Who can forget the **iconic** "Earthrise" images of the Apollo era? And now, from the International Space Station, we have these spectacular vistas. The blue marble is finally revealing its secrets. It's a planet alive with activity and constant change, its surface transformed by humans, yet still ruled by powerful natural forces that we are only beginning to understand.

WALEED ABDALATI: It's just spectacular when you view it from space. It's **teeming** with diversity, with beauty, amazing colors, you know? The blues and the greens and the whites.

PIERS SELLERS (NASA Goddard Space Flight Center): You see the world as one huge system, all linked through the atmosphere and the oceans, rolling its way around the sun.

NARRATOR: So what is it that shapes Earth's dynamic face? What are the essential ingredients, and how do they combine to generate and sustain all life? How do the natural forces that surround us work together to create an engine powerful enough to nourish and drive life forward, in all its diversity?

Our best hope for answers may come from above. Orbiting over our heads are 120 satellites keeping watch from space. Most operate at altitudes ranging from a few hundred miles above the surface of the planet to as high as

25,000 miles. Each one of these Earth-observing satellites reveals a different piece of the puzzle. Each carries an array of exquisitely sensitive detectors designed to reveal what would otherwise be hidden from our view.

EMILY SHUCKBURGH: The satellites are absolutely amazing because, not only can we see visible things from space, but, also, we can see things that aren't visible to the human eye. So satellites are enabling us to turn what are invisible processes into visible things we can see and then understand.

NARRATOR: To see how our world works, in this program we have taken information provided by satellites, combined it with computer models, and **rendered** the results in these scientifically accurate graphics.

With the invisible now revealed, we can see Earth as an endlessly changing system.

These images will show, in great detail, how sunlight, moisture, land and atmosphere interact in unexpected ways, with seemingly local events often triggered by forces far away in space and time. And with these new insights, for the first time, scientists can begin to understand the intimate relationship between the planet and all the living things it supports.

WALEED ABDALATI: It's really the thrill—because it matters so much—of piecing together the story of what the earth is doing, how it's changing, why it's changing and how, ultimately, that affects humans.

NARRATOR: The first piece of the puzzle is in understanding the massive influence the sun, from 93 million miles away, has on our planet.

PIER SELLERS: The world's continuously bathed in a flow of energy from the sun. That warms the earth. Everything that you can see that lives and breathes and moves on the earth is pushed by the sun.

NARRATOR: Now an electronic eye in space can measure the impact of the sun's energy all around the earth. One of NASA's newest satellites, named for a meteorologist, polar-orbiting Suomi, launched in 2011, provides the view. The spacecraft is the size of a small school bus. It orbits 500 miles up, circling the planet 14 times a day. On board, it carries five separate sensors that enable it to see things invisible to human eyes.

The light that we can see is confined to a narrow band of electromagnetic radiation, just a tiny portion of what the satellite can pick up. Electromagnetic radiation **spans** a spectrum that goes far beyond the familiar colors of the rainbow.

WALEED ABDALATI: If you were to consider the full spectrum to be a line that stretched from New York City to Los Angeles, the piece that our eyes could see would be about the size of a dime. There is so much other information out there available to us, and that's, in large part, what these satellites do.

NARRATOR: One of this satellite's key instruments is called CERES, an acronym for "Clouds and Earth's Radiant Energy System." It detects a broad range of the spectrum, including the very short and very long wavelengths of light in the ultraviolet and infrared that we can't see.

This is a CERES-eye view of the planet.

Anything that emits heat gives off **infrared radiation**, so the CERES data shows the earth in shades of heat, accurate to a fraction of a degree. It reveals how the planet, as a whole, reacts to sunlight, both absorbing and **reflecting** the radiation coming from our local star.

At the poles, the sun strikes at an **oblique angle** and what little light there is, gets reflected back out to space by the ice and clouds. These are the primary reasons why the poles remain cool.

At the equator, it's a very different story. Not only does the planet receive more direct sunlight here, the lack of ice means that less of the sun's energy is reflected back into space. And at the equator, the sun's concentrated energy fuels a heat engine that can trigger weather events around the world. Perhaps the best place to see the impact of the sun's heat is an area in the Atlantic, just north of the equator and west of Africa: the coastal waters of the Cape Verde islands.

Here the sea provides a living. The local fishermen keep a careful eye on the weather. They know that storms can bring a good catch. **Turbulent** weather stirs up nutrients from the deep, attracting great shoals of fish.
It's the hottest time of the year, and the sun beats down **relentlessly**. By late afternoon, the huge inflow of heat energy has led to the buildup of large cloud formations. Sometimes these formations develop into **massive** storms.

It's a process that satellites are revealing in fine detail. Circling above the fishermen is a NASA satellite called Aqua, Latin for water. It orbits the poles. One of its key tasks is to monitor the complex interaction between sunlight and water.

JEFF HALVERSON (University of Maryland, Baltimore Campus, Meteorologist): Aqua satellite is one of NASA's flagship satellites. Its primary function is to study the **hydrologic cycle** on Earth: vapor in the atmosphere, liquid ocean, the temperature of that ocean and the ice.

NARRATOR: One of Aqua's instruments looks down at the sea around Cape Verde, again, in infrared, sensing heat. Highlighted here, in yellow, over 1,000,000 square miles of ocean reaches a critical temperature: 80 degrees. At this temperature, the sea is evaporating fast, producing an invisible gas: water vapor.

EMILY SHUCKBURGH: By looking at the infrared, the Aqua satellite is able to measure the amount of water vapor evaporating from the surface of the ocean.

NARRATOR: Aqua shows that this area is producing millions of tons of water vapor every hour. Based on that data, it's possible to create an image of what the vapor might look like, if these fishermen could actually see it in the air around them.

Water vapor is much lighter than air, and vast columns rise upward, directly from the surface of the sea. The water vapor carries with it heat, the energy of the sun.

JEFF HALVERSON: Well, water vapor is like invisible energy. It's like molecules escaping the ocean, taking heat energy with them. And they're like little mobile solar collectors that are zipping around the atmosphere.

NARRATOR: Half a mile up, as the air cools, the water vapor **condenses** back into liquid water, tiny droplets that form vast clouds. The vapor releases the sun's energy, the heat it received earlier. The result is a storm.

JEFF HALVERSON: Molecules condense in the atmosphere and become liquid again, and when that happens, that heat is given off into the atmosphere and warms the atmosphere, and that's the heat that powers storm systems.

NARRATOR: In the worst storms, the heat captured by the water vapor is equivalent to up to 200 times the global production of electricity at any given moment. The process of evaporation results in something we don't need special instruments to see: the rising heat drives the clouds up to 10 miles high. As the clouds rise upward, the earth's rotation causes them to spin. The thunderclouds merge into a vast vortex. This is the birth of a hurricane.

It is 2005, the busiest hurricane season on record. On August 27, a **meteorological** satellite is tracking a Category 3 hurricane that started in the Bahamas. Its name is Hurricane Katrina. Throughout the region, there is one question on everyone's minds: "Will the hurricane hit land, or will it blow itself out?"

The answer may come from a NASA satellite called T.R.M.M., the Tropical Rainfall Measuring Mission. T.R.M.M. is equipped with a radar and imager that operate in the microwave range of the spectrum. These are higher in energy and shorter in wavelength than other radio waves.

The instruments bounce microwaves off raindrops in the clouds, allowing scientists to build a three-dimensional model of the internal structure of a hurricane.

JEFF HALVERSON: We can actually look at **microwave energy**, which is generated within the clouds and coming from the ocean surface. It's almost as if the clouds are now invisible to us. We can see right through them, like taking a CT scan, to look inside those clouds.

NARRATOR: This satellite is a powerful tool. And now its sensors reveal something ominous: huge, vertical columns of warm water vapor burst up from near the center of the storm. Almost like hurricanes within hurricanes, these climbing **vortices** deliver added **infusions** of energy into the heart of the storm, fueling its growth even more. These new sources of energy are called "hot towers."

JEFF HALVERSON: If they occur in the right place at the right time, in the very center of the system, they can be like a giant sparkplug that gets that whole engine running at very, very high speed.

NARRATOR: The hot towers draw more and more water vapor off the ocean. This triggers a feedback loop that leads to a runaway reaction. In just 24 hours, Hurricane Katrina grows into a Category 5 monster.

All this violence is a direct result of the power of the sun on the ocean. Ferocious winds blow for two days straight, reaching 175 miles per hour, twisting steel like paper and ripping apart homes and buildings. Over three trillion gallons of rain a day and a massive **tidal surge** from the Gulf of Mexico combine **to inundate** whole areas of the Gulf Coast.

Katrina leaves its mark across 90,000 square miles. Over a million people are displaced. Katrina becomes the standard by which future hurricanes will be assessed.

But even this extreme hurricane is just a tiny brushstroke in a much bigger picture: a picture of how the sun drives water around the entire planet, with radically different effects in different places, all under the watchful gaze of our eyes in space.

Take just a single day in July: in New York, commuters swelter in 95 degree heat; **searing** winds pump hot air into the region from the south, creating oppressive, humid conditions. Seven thousand miles away, in Mumbai, India, commuters, here, struggle to cope with **torrential** rain; the **deluge** comes so fast that the streets are flooded in hours. Meanwhile, in Chile, the desert of the Atacama is almost totally dry; there are places here where rainfall has never been recorded. Such diverse environments, thousands of miles apart, appear totally unrelated. But by pulling back for a wider view, we can see that they are, in fact, intimately are connected.

Orbiting 22,000 miles from earth's surface is a chain of five weather-tracking spacecraft, including this one: GOES East, operated by the National Oceanic and Atmospheric Administration. GOES is an acronym for "Geostationary Operational Environmental Satellites."

Each moves in a fixed position relative to the earth, called a **geostationary orbit**. They always look down on the same parts of the planet. The combined data from these five satellites gives scientists a unique perspective on the earth.

EMILY SHUCKBURGH: By having several of them located at different positions around the equator, we're able to get a view of the whole earth, 24 hours a day.

NARRATOR: By observing the entire earth, these satellites reveal how energy moves throughout the globe, beginning with the impact of the sun on water. The process is the same everywhere, but the outcome will be very different in different places.

Converted from the numerical data, these five circles graphically depict what the satellites actually sense. They reveal the total picture of the water vapor produced on Earth, in a single frame.

Seen here in fast forward, one second is equal to a day. It shows how water vapor produced at the equator continuously transports the sun's energy towards the poles.

Local landscape and topography affect the vapor's impact, with results unique to each region.

In India, at the end of July, the warm water vapor is drawn from over the ocean by the difference in temperature between land and sea. Rising to high altitude, the vapor cools over the land and condenses back into water. We call the result "the Asian monsoon." Nearly a trillion tons of rain falls out of the sky, transforming **parched** land into fertile plains.

The monsoon eventually moves to the east, reaching China, where it floods the paddies that are ideal for growing rice. This process helps provide food for three billion people, almost half the world's population.

Meanwhile, on the other side of the world, in South America, westbound winds drive water vapor across the high peaks of the Andes. The altitude strips the air of its moisture, which falls as snow on the mountains, creating, on the far side, in central Chile, the arid desert of the Atacama.

That same July day, in the eastern United States, hot moist air surges north, straight from the Gulf of Mexico. With no natural barrier in the way, more than 100 million Americans, from Memphis to New York, **swelter** in the summer heat.

This graphic, based on information provided by satellites, depicts the interaction between the atmosphere and the oceans, as they connect in a global pattern of circulation that results in our local weather.

EMILY SHUCKBURGH: The satellite data shows that it's all one interconnected system, but that, in different parts of the world, different processes are happening. We can see the monsoons and their effect; we can see the effects on deserts in a different part of the world. And that, together, shows us how water vapor is connecting with life on Earth.

NARRATOR: But this vast cycle of sunlight, water and land is just one pattern among many on this planet we call home. A cycle with even greater consequences for the long-term climate involves extreme cold. To see how that works, we have to turn the earth upside down and look at it from below.

Antarctica remains the Earth's last great wilderness: a vast frozen continent, plunged in darkness for almost six months of each year. In winter, temperatures can drop below minus-110 degrees Fahrenheit, and an **incessant** hundred-mile-an-hour **gale** blows. It's hard to believe that anything life-giving could start here, in this **bleak** place, but that's exactly what happens.

Antarctica's ice plays a **vital** part in maintaining global climate, sustaining life, even in lush, warm jungles, thousands of miles away.

WALEED ABDALATI: Antarctica is a fundamental element of the climate system. And, while it may sit silently and majestically at the edge of the planet for very few to see, things go on there that, that spread out all over the world, that affect the world as a whole.

NARRATOR: It's a paradox that such a bleak and **barren** place is so critical to life on our planet. On average, it's 43 degrees colder than the North Pole. Why should Antarctica be so much colder, and how does that affect the rest of the world?

The detectors on NASA's polar-orbiting satellite, Suomi, provide part of the answer. The instruments sense in the infrared and ultraviolet parts of the spectrum. They show that the poles receive little of the sun's energy and reflect most it back out into space. That's one reason why the poles stay cold. But there's another factor that makes Antarctica colder still.

This image has been pieced together from 17 different satellites that sense the infrared, or heat. The continental mass of Antarctica lies beneath this swirling **maelstrom** of cloud.

A computer model of the data shows what happens as the warm, moist air arriving from the tropics collides with the cold air over the South Pole. The result is a massive storm system and, just like a hurricane, it rotates as a result of the spin of the earth. Only this is much larger than a hurricane: 4,000 miles in diameter.

EMILY SHUCKBURGH: Where that cold air and warm air meet, high up in the atmosphere, the air starts to rotate around Antarctica. The winds can be, up in the atmosphere, as much as 200 miles an hour.

NARRATOR: This circulation pattern is called the polar jet, a **ceaseless** circle of wind and storms. The relentless clockwise wind, seen here in yellow, drives the seawater below, shown in light blue.

DAVID ADAMEC (NASA Scientist): Those strong winds are sending a jet around in the ocean, and it's driving an ocean circulation that is felt almost all the way to the bottom of the ocean, two and a half miles deep.

NARRATOR: The Southern Ocean rings the continent, with no land to interrupt a vast body of moving water. This is the **Antarctic circumpolar current**. And these are the screaming sixties: the roughest, most dangerous seas on the planet. Here, storms rage almost every day of the year, whipping hundreds of trillions of gallons of water into a **ceaseless frenzy**.

Now the infrared instrument on the Aqua satellite, which senses atmospheric temperature, puts the pieces of this puzzle together. The winds of the polar jet and the water of the circumpolar current, together, form an impenetrable barrier around Antarctica, isolating it from the rest of the planet and **depriving** it of warmth. That is why the whole region remains exceptionally cold, all year round.

WALEED ABDALATI: What's incredible about what the satellites tell us is that the movement of air and, actually, the movement of ocean current around the **perimeter** of Antarctica, isolates the continent from the rest of the world.

NARRATOR: So, why is this **relentless** cold so important to the planet way beyond Antarctica? The answer lies in a remarkable property of water: what happens when it freezes. The Aqua satellite reveals the start of the process. It sweeps the surface with its microwave scanner, looking through the clouds, to detect the **distinct** signature of ice.

EMILY SHUCKBURGH: The microwave instruments on the satellite enable us to see through the clouds to the sea ice around Antarctica, throughout the year. What's particularly incredible about that is we're able to take measurements of the sea ice in places where, as scientists, as humans, we can't even go.

NARRATOR: This satellite gives us an accurate picture of the **extent** of sea ice around Antarctica, over the course of a year. Seen here in summer, Antarctica is nearly one and a half times the size of the United States, covered in ice. But in winter it grows even more. Over five and a half million square miles of ice form around the continent. It grows to the size of all of Africa. This vast ice formation has a **profound** impact on life across the planet. How can its impact extend so far?

One of the best places to understand the power of ice is the huge **bay** along the northwestern coast of Antarctica, the Weddell Sea. Here, a constant **gale** blows and cools the seawater to freezing temperatures. Once the upper layer of ocean falls below 29 degrees Fahrenheit, a critical threshold is crossed; the surface of the ocean begins to freeze.

At a microscopic level, tiny crystals start to grow, knitting themselves together. As the crystals bond, they expel salt into the water. The salt forms **brine** that drips down long, narrow tubes and holes in the ice, as it forms. The brine is denser than regular seawater, and it sinks downwards.

As winter's grip tightens, the formation of ice speeds up and spreads. Soon large slicks appear on the surface and thicken into a solid mass. What started as a microscopic process can soon be seen from space.

Each year more than two hundred billion tons of ice forms in the Weddell Sea alone, releasing tens of trillions of tons of dense brine into the ocean. The fate of all this brine is a mystery. The crucial question is, "Where does it all go?"

A satellite called Jason, jointly operated by NASA and the French space agency, is providing new answers. Jason bounces radar signals off the surface of the ocean to measure its height. The instrument also reveals the shape of the seafloor far below.

GENE CARL FELDMAN (NASA Oceanographer): We can make very accurate maps of submarine **bathymetry**, but we don't do that directly. We do that by measuring the surface of the sea from space, very, very accurately and over time.

NARRATOR: Jason's radar is so precise that it can detect **minute** changes in the level of the sea surface produced by the peaks and valleys of the terrain below. The data makes it possible to map the ocean floor.

DAVID ADAMEC: You have a satellite that's up there, 500 miles up in space, and it's returning an accuracy of a little less than half an inch. What that means is, you know... I've stuck this instrument, in Washington D.C., say, and I'm looking at a crowd of people in Boston, and I can tell you whether or not their toes are over the curb or not. That's what this satellite is doing.

NARRATOR: The satellite data allows scientists to make a three-dimensional map of the ocean floor beneath the Weddell Sea. It reveals a **vast chasm**, two miles deep, off Antarctica's continental shelf. As the brine descends into the ocean, it eventually falls over this **precipice**.

Other sensors, attached to the seafloor, track the flow of the brine as it sinks.

EMILY SHUCKBURGH: What we're really excited about is that we're able to take that data that shows us what the bottom of the ocean looks like and combine it with data from sensors under the water, and that enables us to look at the dense water and where it goes.

NARRATOR: Combining data from satellites and undersea instruments, scientists can reconstruct what is happening, hidden beneath the ice. What they learn is astounding. One trillion gallons of salty brine plunge down through the Weddell Sea every hour—a torrent equivalent to the volume of 500 Niagara Falls. The brine spreads out towards the edge of the Antarctic continental shelf and then falls into the chasm revealed by Jason. A vast submarine waterfall **plummets** downward. The cold, dense brine falls slowly, silently, into the **abyss**, two miles down to the ocean floor below. It will not resurface for hundreds of years.

What happens to the brine next is still being investigated, but computer models combined with the satellite data are helping scientists to figure out where it goes. This animation shows the undersea current in action. The purple area is the brine. The outflow from Antarctica drives the salty water towards the equator, along the seafloor.

DAVID ADAMEC: All the water in the bottom of every ocean around the globe has its start within six miles of the Antarctic continent. It creates the coldest, densest water that's on the planet.

NARRATOR: The cold, salty liquid becomes part of a worldwide circulation system, stirring and cooling all the world's oceans. Leaving Antarctica, it has **embarked** on a journey that could take a thousand years to complete. As it migrates towards the equator, the cold bottom current mixes with fresher and warmer water and slowly rises. It then joins other ocean currents and eventually returns south, where it cools once more. Finally, returning to Antarctica, the seawater freezes and releases its salt again, completing the cycle.
It's an endless loop that is critical to the whole planet.

WALEED ABDALATI: The importance of dense water in Antarctica is that it really forms the basis of global ocean circulation. The temperature and the salt combine to cause sinking and rising in different parts, which sets up this conveyor belt, this interaction of all of the ocean waters.

NARRATOR: In the Arctic, frigid winter winds cause the ocean to freeze. The North Atlantic currents cool and sink to the bottom, then head south again. All over the world, slow-moving currents of seawater, like this, **regulate** the average temperatures of the oceans, to within one degree. This stability has a profound effect on life all across the world.

This NASA simulation shows the surface of the entire ocean, a web of currents in constant motion, but satellites show us that the oceans don't work alone. The currents affect the air, the atmosphere, that sits above them. The ocean and atmosphere are intimately connected. For instance, the Gulf Stream takes warm water from the Gulf of Mexico north to the eastern United States and Europe, **generating** warm air.

On the other side of the world, another current, called the Kuroshio, carries heat from China, north to Japan. It's a global process, ocean currents **distributing** heat around the planet.

WALEED ABDALATI: The climate we live in is a result of ocean circulation patterns. The reason, in the United States, that North Carolina and South Carolina are warm is because there is the Gulf Stream. And the reason there's a Gulf Stream really takes root in Antarctica.

NARRATOR: As a major engine, driving the world's ocean currents, Antarctica helps protect Earth's climate from wild swings in temperature. The constant, dependable circulation of the oceans around the globe and the relatively stable temperatures it produces, have made Earth a **hospitable** planet. Long-term stability provided time for life to **flourish** and complex animals and plants to evolve. And this is how a process that began with Antarctic ice continues to **sustain** our world.

WALEED ABDALATI: When you put it all together, you get a story about how ocean circulation affects climate and weather, and what that means today, tomorrow and 20 years out into the future.

NARRATOR: But ocean currents and the atmosphere are not the only players. Beneath the seafloor, forces inside the earth are a **crucial** source for the basic materials that nurture life. This hidden mechanism is driven by ceaseless, often violent activity.

Two recent examples: a magnitude nine earthquake strikes Japan in 2011; an entire section of the country moves eight feet towards North America. A year earlier, two and a half thousand miles to the south, in Papua, New Guinea, the volcano Rabaul erupts. It fires a **vast plume** of ash high into the atmosphere. These are catastrophic, hugely destructive events, with an enormous cost in human lives. But the natural forces behind these disasters also provide the materials we and other living organisms need to survive.

And satellites help show us how this happens. Canada's RADARSAT, is one of several satellites that use highly sensitive radar to map the earth's surface in three dimensions. Bouncing radio waves off the terrain below, these satellites continually **sweep the surface** of the globe. They can measure the height of the earth's surface, every day, to an accuracy of less than a quarter of an inch. When the data is plotted over time, we can see, in fine detail, how the earth's crust is constantly moving.

This is the surface of the crater atop Mount St. Helens, in Washington State. Animation reveals how the crater swells over the course of three weeks, driven by a surge of molten magma beneath the crater.

PIERS SELLERS: The satellites can actually see the crustal plates moving now. We can see **bulges and dips** where the magma is moving around underneath.

NARRATOR: This animation shows the swelling of Mount Etna, in Italy, as magma accumulates beneath it over nine years. When the volcano erupts, the land sinks back.

PIERS SELLERS: So, we're getting a picture, now, of what the world looks like under the crust and how that affects the other dynamic processes of the so-called solid Earth.

NARRATOR: Every day, dozens of volcanoes around the world are erupting, while 4,000 earthquakes shake the ground. Our earth is dynamic, constantly ejecting gases and magma from its depths, and some of this activity has a **vital impact** on life.

The secret to understanding how lies deep beneath the ocean's surface. Here, a crucial chemical reaction takes place, between molten rock and deep ocean water.

The Jason satellite's sea-surface mapping radar reveals a chain of active volcanoes a mile and a half down, at the bottom of the Pacific Ocean. This is where that critical interaction between molten rock and freezing water takes place. This footage was taken with a remotely operated submarine, also called Jason.

Lava and superheated gases spill out of cracks in the ocean floor, known as **hydrothermal vents**. Jason reveals what happens when the ocean water **penetrates** into the cracks. A magma chamber below heats the water up to 750 degrees Fahrenheit. In the pressure-cooker environment inside the cracks, the dense salty water actually dissolves the solid rock. Complex chemical reactions take place, producing minerals containing sulfur and iron. These are nutrients that living organisms need to survive. The seawater, now loaded with minerals from inside the earth, streams out of the hydrothermal vents. These nutrients feed a thriving ecosystem that includes shrimp and exotic creatures, like tube worms.

The deep ocean currents carry the leftover nutrients away. Over thousands of years, they circulate through the oceans, ultimately rising to the surface, and contributing to an amazing explosion of life.

And we can see this activity with NASA's Aqua satellite, which is equipped with instruments that observe the earth in many wavelengths of the electromagnetic spectrum. One tool is called MODIS.

PIERS SELLERS: MODIS is pretty much **the crown jewel** of the Aqua satellite. It's an enormous scanner so; it basically covers the whole world, every day.

NARRATOR: MODIS scans the ocean in the infrared and the visible portions of the spectrum. It can detect extremely subtle changes in the temperature and color of the water.

GENE FELDMAN: So, what we have in space is an instrument that looks at very, very small parts of the spectrum, and we measure how much light comes back in each part of the spectrum.

NARRATOR: Looking down at the west coast of South America, MODIS detects an **upwelling** of cold water, 150 miles west of Peru. Then it detects a particular shade of green. This identifies the source as chlorophyll, a sign of plant life. It's clear that the satellite has spotted a **massive bloom** of tiny organisms, called phytoplankton. Just below the surface, these phytoplankton are absorbing the rich soup of minerals that have come from the deep ocean, and with the light from the sun and carbon from the carbon dioxide in the air above, they multiply by the billions.

As MODIS shows, the plankton multiply so quickly that in just 24 hours, 500 square miles of ocean have turned to this **distinctive** green color.

GENE FELDMAN: They **replicate** very, very fast. You can have a plankton bloom that doubles over the course of a day and can cover hundreds or thousands of kilometers of the ocean surface.

NARRATOR: It's the minerals from beneath the earth's crust that have helped fuel this vast explosion of plankton: over 800,000 tons of living material. And that's only the beginning. This plankton is the base of the food chain for marine life. The bloom triggers one of the largest **feeding frenzies** on Earth.

Trillions of anchovies and sardines feast on the tiny organisms. They, in turn, attract larger predators to one of the densest concentrations of marine life anywhere. Sharks converge. And even birds, flying above, dive down to join the feast. And up above, humans are here, too, taking advantage of one of the world's most productive fishing grounds. The satellite data reveals similar upwellings all around the world, delivering nutrients, seen here in pink, into the surface waters.

Each upwelling triggers a plankton bloom.

GENE FELDMAN: Phytoplankton provide that key link between this energy out here, the raw materials that this planet holds, and the, the food engine that allows life to **flourish.**

NARRATOR: These vast green ribbons of plankton can cover as much as a fifth of the world's ocean surfaces, about 45 billion tons of biomass every year. The plankton are one link in a chain of life that begins deep beneath the seafloor

GENE FELDMAN: The most important plant life on this planet are these microscopic little green plants that float in the ocean.

NARRATOR: Plankton may be key to life, but they themselves don't live long. MODIS shows how, in just 72 hours, a bloom can rapidly weaken and fade. All the plankton that have not been eaten die and sink into the abyss. They take their precious minerals with them all the way back to the ocean floor. Here they will remain for millennia, a thick carpeting of tiny **carcasses** half a mile deep. Some of the minerals may ultimately be recycled, some may emerge through hydrothermal vents again, millions of years from now, but some plankton, through yet another extraordinary chain of events, will deliver their precious cargo of nutrients, not just to life in the ocean, but also to life on land.

Half a world away from the coast of Peru, where plankton bloom, lies the Sahara Desert in North Africa. The Sahara is enormous. It makes up a tenth of the African continent. It's one of the driest and dustiest places on Earth. Surprisingly, the remains of ancient plankton are here, hidden in this arid landscape.

It is May, the hottest month of all. Camel herders travel through one of the most exposed regions of the Sahara: the Bodele Depression. Six thousand years ago, this was covered by the world's largest freshwater lake. The floor of the lake is covered with the ancient remains of plankton, called diatomite, laid down in a much earlier age, when an ocean covered the region.

With its eye on the earth, from 400 miles above, NASA's Landsat 7 is one of the latest generations of satellites studying the composition of rocks that make up our planet. It sweeps the Bodele, producing these high-resolution pictures in multiple wavelengths of visible light. The white expanse is the diatomite on the bed of the lake.

CHARLIE BRISTOW (Birkbeck, University of London): The size of the lake is over a thousand kilometers long and 600 kilometers wide. But, with a satellite image, we can see the whole extent of the basin on a series of images and visualize that, on a computer, in a matter of minutes.

NARRATOR: The satellite image analysis shows over 24,000 square miles of sediment, all of it diatomite.

CHARLIE BRISTOW: We can map where the diatomite sediment is on the floor of the lake.

NARRATOR: The diatomite from the plankton is a rich source of phosphorous, an element needed by all living things to produce energy. But for this nutrient to re-enter the chain of life, it must first embark on a long journey that can be seen from space.

The journey begins here on the ancient lakebed in the Sahara. The wind sweeps up a few flakes of diatomite into the air; the flakes **fracture** into a fine powder and are carried off by the wind; a dust storm builds. Twenty-two thousand miles above, the European weather satellite METEOSAT 8 looks down from its geostationary orbit. It records a daily pulse of dust rising off the Bodele Depression. Here, it's visible as a whitish dust cloud, lifting from the desert, with clockwork regularity, at noon, each day.

CHARLIE BRISTOW: Although the individual particles of dust are **minute**—they're hundredths or thousandths of a millimeter in diameter—there are such vast clouds of this dust that you can see it on satellite images.

NARRATOR: The dust cloud is over a hundred stories high and 200 miles wide. From here it will head west on an **epic** journey.

Seen from space, the dust is blown across Africa. At the Atlantic coast it's drawn up high into the sky. This simulation, based on satellite data, shows how **prevailing winds** carry the dust cloud west and south, 3,000 miles across the Atlantic. As much as 7,000 tons of dust are airborne at any one time.

The destination is set by the winds: South America and the Amazon.

CHARLIE BRISTOW: We're taking literally thousands of tons of this dust, which is containing phosphate, and exporting that from the Bodele. The wind is carrying it out across the Atlantic to fertilize the Amazon.

NARRATOR: Here, in these clouds, high above the rainforest, what was once living plankton reaches the end of its journey. The minerals in the dust, which include energy-giving phosphorous, dissolve into water droplets and fall to the Amazon, in rain.

CHARLIE BRISTOW: Areas like the Amazon jungle, although they appear very rich, the soils are actually very **depleted**, they've been **leached**. And one of the things that they're short on is phosphate.

NARRATOR: Rain falls **incessantly** throughout the Amazon's wet season, delivering thousands of tons of phosphate into the forest below. It passes into the soil and the roots of trees, nourishing the rainforest. The effect of all this natural fertilizer can be seen clearly from orbit.

Terra is the twin of the Aqua satellite. It circles the earth every 99 minutes, monitoring how fast vegetation is growing.

PIERS SELLERS: We can see all the green vegetation on Earth, wall to wall, every day, and it tells you almost everything you want to know about the state of life on Earth.

NARRATOR: With its color scanner, Terra can see the effect of the Sahara dust on the Amazon at the end of the rainy season. It observes an increase in the distinctive green color of chlorophyll. Like the plankton blooms in the ocean, the forest is **kicking into overdrive**, watered by rain, and nourished by the minerals **borne across** the Atlantic by the dust cloud. For every leaf that exists now, three more will grow in a week. It's the **culmination** of a chain of events that began far back in time and half way around the world.

PIERS SELLERS: So ancient sediments, laid down by other organisms millions of years ago, get **eroded**, make dust, the winds bring them across the Atlantic, fertilize the tropical forest in the Amazon.

NARRATOR: The migration of Bodele dust to the Amazon is just one of many ways that vital minerals spread to living habitats all over the world. Every landscape has its own story and its own way of entering the chain of life.

CHARLIE BRISTOW: The exchange of nutrients from the land is going on all over the globe, every day.

NARRATOR: And in certain areas, this is what accounts for the special **productivity** of the soil. The great plains of North America are rich in minerals eroded from the Rocky Mountains. These are vital ingredients for growing wheat and corn. In Bangladesh, the Ganges Delta is rich in iron, washed down from the Himalayas in river sediments, ideal for growing rice. The hidden transport of minerals creates fertile soils that enable plants to **thrive.** These minerals are the basis of the food chain for all life on land, including us.

PIERS SELLERS: And all of this reminds you how interconnected the earth system is, that no living thing lives in isolation from processes that may happen a long way away—in both space and time—from itself.

NARRATOR: Satellites provide a vivid new perspective on the links between land, sea, air and life. This new perspective helps us see how the natural forces of our planet fit together, and that includes the atmosphere and something as basic as the air we breathe.

Less than a quarter of the air around us is **comprised** of oxygen, but that oxygen is essential to life. It's what all animals need to burn fuel in their bodies. Oxygen is vital to metabolism. It provides the energy that allows even the most active creatures to survive and thrive and to master their environments. Scientists believe that the abundance of oxygen in the atmosphere was essential for the evolution of large, intelligent mammals, like us. The human brain alone uses about 20 percent of the oxygen we breathe. But where does all this oxygen come from?

Satellites can help us answer that question. NASA's Aura satellite is one of several spacecraft that are helping scientists study the earth's atmosphere. Along with ground instruments, it can analyze the atmosphere and pinpoint its composition. It builds a picture of the nitrogen, oxygen and carbon dioxide that, together, make up 99 percent of the air we breathe.

This computer visualization shows how the earth's atmosphere changes over 24 hours. During the day, oxygen, seen here in blue, rises all over the planet; at night, carbon dioxide, shown in orange, is on the rise. And the oxygen we need is given to us by plants.

PIERS SELLERS: Before plants, there was no oxygen in the atmosphere, so plants did all the hard work of allowing the atmospheric concentration to build up over time, allowing all other life to develop. They made the place habitable for us.

NARRATOR: Plants breathe in carbon dioxide and **expel** oxygen. They produce so much that the vast Amazon rainforest is often called the lungs of the earth. But the real picture is more complex.

The verdant wilderness of plants and animals is one of the oldest, most **abundant** living systems on Earth. Over 2,000,000 square miles of lush rainforest teem with half the world's living species.

PIERS SELLERS: The Amazon is the largest natural preserve of life on the continents that's left in the world: thousands of miles of almost virgin forest, thousands of species that have been there for an awfully long time.

NARRATOR: So dense is the Amazon jungle that it has a dramatic impact on the air above it. It starts in the trillions of leaves far below.

We can use animation to show what this invisible process, known as photosynthesis, might look like. During the day, the leaf takes up carbon dioxide from the air, seen here in orange. It converts the carbon into sugar for energy and growth, and releases oxygen, seen in blue.

Each one of these trees will release hundreds of thousands of cubic meters of oxygen in the course of its life. And as for the Amazon as a whole, a fifth of the world's oxygen is produced here. But there's a surprising twist: we will breathe almost none of it. Satellite data and ground measurements reveal that almost all the oxygen the Amazon produces during the day remains there and is reabsorbed into the forest at night.

PIERS SELLERS: With the advantage of the satellites, we can now see that the Amazon basically uses all its own oxygen and uses all its own carbon dioxide. It is, as far as we can tell, almost a closed system, in itself, almost.

NARRATOR: But the Amazon still plays a vital part in **generating** the oxygen that we breathe. What satellites now make clear is producing the oxygen that benefits us takes an extra step.

The process begins with rain, which falls up to 250 days a year in the Amazon. The soil of the rainforest is continually washed into the Amazon river system, taking with it nutrients and organic material. An average of 2,000,000 tons of this sediment is released every 24 hours. The sediment flows eastward, traveling 4,000 miles into the Amazon delta. Here, microscopic plankton near the surface **thrive** on the nutrients, and their population explodes. As they spread further out to sea, some of these tiny organisms act like plants, absorbing carbon dioxide and releasing oxygen.

Again, the Aqua satellite shows us how a giant plankton bloom grows to cover 25,000 square miles. This vast area translates into a huge boom in oxygen production, made available to the entire planet.

GENE FELDMAN: When plankton grow they release oxygen. That oxygen ultimately finds its way into the atmosphere.

NARRATOR: The **massive** scale of this impact is revealed when the satellite data is visualized.
This animation shows the oxygen produced by plankton blooms, seen here in bright blue. The Amazon plankton bloom releases billions of gallons of oxygen into the atmosphere every day. Within a few days, the plankton die, leaving most of the oxygen they produced in the air, as they sink to the bottom of the ocean. Similar explosions of microscopic life happen all over the world.

Plankton's major role in replenishing the oxygen in the atmosphere is something we've only fully grasped with the help of satellites.

GENE FELDMAN: Satellites gave us that very first global picture, global assessment of what the oceans' plants were doing.

NARRATOR: And what plankton are doing is providing life-giving oxygen for us.

GENE FELDMAN: Plankton in the ocean are responsible for over half of the oxygen that we breathe, and it's what most creatures on this planet rely on to survive.

NARRATOR: Microscopic organisms, as well as rainforests, are the real lungs of the earth.
So what other secrets of life can satellites, our eyes in space, reveal? It turns out that another surprising way life is **sustained** is through a violent force: lightning.

From orbit, the whole earth buzzes with electricity. Astronauts are often amazed by the intensity of the electrical storms raging far beneath them.

PIERS SELLERS: You can see a thousand miles' worth of lightning flashes, left and right, as you're looking down, and they seem to set each other off, like fireworks: bang, bang, bang, bang, bang. It's really quite amazing.

NARRATOR: But to understand lightning's global impact we need more than just observation. NASA's T.R.M.M. satellite carries a high-speed camera that can detect individual lightning bolts. From this information, it's possible to build a picture showing the distribution of lightning all across the globe. Astonishingly, 40 strikes occur every second. That's more than 3,000,000 strikes a day.

So how is all this lightning created? And what is the effect of all this energy streaking through the earth's atmosphere?

Each day, the combined force of sunlight and water vapor creates 40,000 thunderclouds. The rising columns of moist air generate powerful updrafts that turn water vapor into ice particles inside the clouds. As ice and water droplets smash into each other, at great speed, vast charges of static electricity build up. An average thundercloud contains enough energy to power a city the size of Denver for 10 hours. Eventually, the charge builds to a point where air molecules are torn apart and a lightning bolt is born.

A bolt is no thicker than a human thumb, yet it's five times the temperature of the surface of the sun. As it burns through the atmosphere, the electricity breaks apart the molecules of nitrogen contained in the air.

DAVID ADAMEC: A lightning stroke, it actually splits the nitrogen into single nitrogen molecules (*atoms). Nitrogen doesn't like that. It's desperately looking for something to connect back to with, and it often does it with oxygen.

NARRATOR: When oxygen bonds with the nitrogen, it creates a vital nutrient called nitrate. Satellites show the extent of nitrate, simulated here, in yellow, produced by the more than 3,000,000 lightning bolts that strike every day. This creates about 13,000 tons of nitrate. It dissolves into water droplets in the clouds and falls to the ground, in rain.

DAVID ADAMEC: Most people are familiar with nitrates because they're fertilizers. So when it rains, in a thunderstorm, in a way, you're getting a free fertilizing, because the water will have nitrates in it.

NARRATOR: Nitrate is absorbed through the roots of plants and enters the food chain. When we eat these plants, the nitrates become available to us. And so, this vital nutrient enters the cells of every living organism on Earth, where it is critical for building the structure of plants and helps make proteins and DNA in our bodies, as well. It is essential for the survival of all living things.

But nitrate production is not the only way in which lightning **promotes** life on Earth. In the Canadian Yukon, a massive wildfire **devastates** over 10 square miles of forest, in less than a week. Such blazes often start with a random bolt of electricity from the sky. In distant Siberia, over 1,500 square miles of forest burn to the ground, sparked by a lightning bolt.

These flames may seem purely destructive but, thanks, in part, to satellites, we see that they can also be life-giving.

The Terra satellite can detect the location of every fire on Earth, by looking at its **heat signature** in infrared.

PIERS SELLERS: Terra basically gives us a map of all the fires, in all the forests and grasslands of the world, every day.

NARRATOR: This sped-up visualization of Terra's data shows a year's worth of fire, all around the world. The vast swathes of orange are actually thousands of tiny dots. Each one represents a half square mile of land where a fire has burned: over 19 million square miles in total.

The Terra data also reveal fire's role in renewing life.

PIERS SELLERS: The observations have shown us how important fire is as an element of change.

NARRATOR: The benefits of change can be witnessed in the forests of northern Canada. This is a vibrant forest but it has its share of dead and diseased trees. Locked inside them are ingredients that are essential for new life: elements like carbon, sulfur and phosphorous. Yet in a cold environment like this, trees take decades to decompose and return these elements back to the soil. Fire can shorten the cycle to a matter of hours.
The pine tree is highly flammable. It's full of sap and resins that burn easily. The oxygen in the atmosphere fuels the flames.

DAVID ADAMEC: When you're looking at fire, you're looking at a rapid oxidation. That's what fire is.

NARRATOR: Within a matter of hours, what may have started as a spark from a single lightning bolt turns acres of forest to flames. The nutrients these trees have stored for so long end up in the ash.
Fires also **consume** the dead animals whose bodies litter the forest, returning the nutrients they contain back to the soil. The smoke climbs into the sky, and the ultimate impact of this nutrient-rich ash can eventually be seen from space.

With its infrared sensor, Terra can pick out the heat given off by the leaves of healthy new vegetation that grows after fire. A **pulse of new growth** follows every blaze.

PIERS SELLERS: Huge areas of forest get burned down quite regularly, and they're followed, almost immediately, by rapid re-growths.

NARRATOR: In forests all over the world, the data from Aqua and Terra show that, within months, large areas that were devastated by fire are **rejuvenated.** From a global perspective, wildfires are essential to the cycle of life.

PIERS SELLERS: Fire's like a great blender for all the materials in the earth system, so when you get dead living material, particularly in the forests, fire will rip through there and decompose that stuff, very quickly, into its basic minerals and compounds that new life can use almost immediately.

NARRATOR: Fire is such an **intrinsic** part of nature that many plants have evolved to make active use of it. The pine tree drops its seeds in the ashen aftermath of a blaze, to make the most of the nutrients that have been released. Wildfires are essential to maintaining the health of many of the world's ecosystems. It's a mechanism by which habitats that are no longer productive regenerate.

We can now follow this process over decades.

PIERS SELLERS: When you look at 30 years of satellite data you see this continuous, dynamic rearrangement of the biosphere. The nutrients that that tree has pulled up from the soil are being dropped back down again, on the soil, to feed the next generation.

The effect of all this is to allow the biosphere to turn over, far more quickly and efficiently.

NARRATOR: By looking at the world from orbit, we see our home planet anew. We discover countless hidden connections, all linked to life. The circulation of weather and ocean currents affects the **ebb** and flow of ice at the poles. Originating in the earth's crust, erupting magma interacts with cold, ocean water, producing nutrients that rise to the surface and nourish aquatic life. Eventually, airborne in dust, nutrients travel around the planet, finally enabling tiny plankton to fill the air with oxygen. That allows complex animals, like us, to survive.

Oxygen also allows fire to burn, which, in turn, accelerates the pace of death and rebirth in the forest.
Above all, life's major driver is the energy we receive from the sun. As the earth rotates over 24 hours, the planet responds to the incredible power of the sun, our local star. Each day, more than a million **terawatts**, over 7,000-times our global energy consumption, strike Earth. This triggers a wave of activity around the globe. At dawn, plants on land and plankton at sea begin to photosynthesize and grow; at the same time, sunlight drives wind and weather around the globe.

We are also part of this cycle, as our bodies respond to the daily inflow of energy from above. Our skin cells use sunlight to create essential vitamins.

Even the flight paths of planes reveal our intimate relationship with the rhythms of day and night. Aircraft travel west in the morning, to extend the day, and east in the evening, to reduce the night.

But while the sun nurtures all life on Earth, it also has the power to destroy. And with the help of a very different kind of satellite, we are coming to understand just how great a threat it can pose.

Orbiting 22,000 miles above the earth is the Solar Dynamics Observatory. This satellite looks, not at the earth, but away from it. Its task is to observe the radiation released by the sun, what scientists call "space weather."

HOLLY GILBERT (NASA Solar Physicist): We have this wonderful new satellite that is up in space looking at the sun, 24 hours a day, and is providing **unprecedented** images of the sun and where space weather is born.

NARRATOR: These striking pictures are produced by the S.D.O.'s ultraviolet sensor, detecting light frequencies beyond the blue end of the visible spectrum. The sun emits constant light, heat and other forms of radiation, along with occasional dangerous bursts of charged particles.

HOLLY GILBERT: Most people don't realize that the earth is exposed to charged particles that are constantly coming away from the sun, at about a million miles an hour.

NARRATOR: Sometimes a massive pulse of those charged particles erupts from the sun's surface. It's called a **coronal mass ejection** and it contains billions of tons of charged particles, superheated to tens of millions of degrees, and blasted out at millions of miles per hour. It has the potential to **wreak havoc** on our planet.
This supercomputer visualization shows what happens when a coronal mass ejection occurs. The explosion is equivalent to 14,000,000 Hiroshima bombs. It sends a cloud of charged particles, millions of miles wide, racing towards Earth.

Without some kind of protection, these enormous blasts would strip away the atmosphere, destroy our fragile ecosystems and scorch the earth. Over time, repeated coronal mass ejections would even cause the oceans to dry up, leaving behind a planet as barren and bleak as Mars.

Fortunately, the earth has an invisible shield, a magnetic field that satellites are now enabling us to better understand.

Orbiting between 40- and 120,000 miles above the earth, NASA has a network of satellites called THEMIS. Each is equipped with highly sensitive instruments that can detect the strength of magnetic fields.

HOLLY GILBERT: THEMIS is a series of probes that are aligned along the earth's **magnetosphere**, and they detect variations in the magnetic fields.

NARRATOR: This computer model, using THEMIS data, shows how an invisible magnetic force field called the "magnetosphere," protects the earth. It's generated by the rotation of the earth's core.

HOLLY GILBERT: THEMIS allows us to build an overall picture of the structure of the magnetosphere and how it operates.

NARRATOR: THEMIS reveals how the magnetic field is constantly blasted by the sun. The wave of charged particles called the solar wind **distorts** the magnetosphere into a gigantic teardrop shape, 120,000 miles across. As wave after wave of solar particles strikes the outer magnetosphere, most are **deflected**. But when a coronal mass ejection arrives, it tears open the magnetosphere, allowing a vast number of charged particles to **breach** the magnetic field's first layer. The particles are free to rush in towards the planet.

But the earth has a second line of defense. Inner magnetic fields steer the radiation down towards the poles.

HOLLY GILBERT: This process is extremely energetic. Particles get accelerated, and then they travel down, along the magnetic field lines, towards the polar regions.

NARRATOR: The radiation streams downward, encircling both the North and South poles, and triggers something we can see with our own eyes, one of nature's true wonders: the Northern and Southern Lights, or the aurora. As the radiation strikes the upper atmosphere at extreme speed, it excites the air molecules. This makes them glow. The oxygen in the air radiates red and green, the nitrogen, red and blue.

HOLLY GILBERT: These charged particles that originated from the sun get trapped and then interact directly with the earth's atmosphere, causing these beautiful colors. So, when we're looking at the aurora, basically, we're looking at the fact that the sun and the earth are intimately connected.

NARRATOR: The aurora is a vivid reminder of how **potentially lethal** energy from the sun is dissipated in the upper atmosphere. The earth's magnetic field has shielded the planet from the sun's deadly radiation for billions of years, enabling life to take hold and flourish.

Satellites are revealing one final piece of this incredible puzzle: the role that humanity plays. Our human footprint has grown so large that we have become a major global force in our own right. Our impact is the consequence of a system that has created and sustained life for three and a half billion years.

Our success as a species has resulted in rapid population growth. And today, our presence can be seen across 80 percent of the landmass. Now we, in turn, are affecting the many natural cycles that govern our planet. Looking for signs of pollution, the environmental satellite Aura's infrared sensor reveals the atmosphere's chemical fingerprint and shows us how we are affecting the entire globe. We already manufacture more than twice the nitrate produced by lightning, much of it used for fertilizer and explosives; our factories release more sulfur than all the earth's volcanoes; our industry and transportation produce more carbon dioxide than the Amazon rainforest captures; our cities generate dust, trigger electrical storms and affect rainfall. And these are just a few of our impacts on the earth's natural cycles.

WALEED ABDALATI: Our earth is changing. We're on a path to somewhere, and our ability to understand that path is crucial to success in the future. And satellites help us answer some of the most fundamental questions needed to understand how our planet behaves.

NARRATOR: But there is one key difference between the impact of nature and our own. Unlike volcanoes, the motion of ocean currents or the oxygen produced by forests and plankton blooms, we make conscious decisions about what we do. And here, satellites are crucial once more. The information they provide can help us meet the challenges of the future.

PIERS SELLERS: The real power of satellite observations is they represent **objective** truth. They tell us about what the world actually is doing, not what we would like it to be doing, not what we might fear it to be doing, but what it's actually doing. And it's that that allows us to see change, real change for what it is.

NARRATOR: Satellites are telling us that the oceans are slowly warming. In the past 30 years, the average temperature of the ocean's surface has risen by half a degree. Models suggest this extra heat could be increasing the intensity of hurricanes and violent storms all around the world. Satellite data shows that in Antarctica, ice shelves that took many thousands of years to form, are collapsing, year after year. And in the Arctic, sea ice is diminishing at an alarming rate.

Many factors play a part in dramatic changes, but most scientists agree that human activity, through our release of **greenhouse gases**, is the main driving force.

All around the globe, satellites are recording change, but there is a problem. Just as we are able to capture and measure these changes, many of the current fleet of satellites are coming to the end of their lives. Satellites need fuel to stay in their orbits. When their time is up, they must either use the last of their fuel to boost themselves far away from the earth or descend and burn up on re-entry. It's predicted that the number of NASA's earth-observing satellite systems will go from 20 down to fewer than 10, within the next decade.

The constant stream of information from these vital instruments in space will fade. If we fail to replace these satellites, we could lose our ability to track the web of connections that is fundamental to life.

DAVID ADAMEC: The complex interactions would be absolutely invisible to us, without a larger view of the earth. It's the consistency and the amount of data that they provide that allows us to understand the processes that are going on in the earth that are important to maintaining life as we know it.

NARRATOR: Little more than half a century after the birth of satellite technology, we are still only beginning to realize its possibilities. Our planet **harbors** mysteries beneath its white clouds, blue oceans and **verdant** landscapes, and they can only be solved with the help of these eyes in the sky, looking down at Earth, from space.