REMOTE SENSING

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(Barry Keim, NH State Climatologist) What remote sensing has enabled us to do is to be able to see large scale systems, see where the weather systems are, where the funnel boundaries are located, where it's clear, where is it raining. So that's added a whole new dimension to weather forecasting and clearly has made it much much more accurate.

(Tom Luther, GIS Specialist-USDA Forest Service) Remote sensing is a data collection technique or a data collection tool that we use to collect information about the resource from a remote position. So flying over the forest in an aircraft, doing what we call sketch mapping, is a form of remote sensing and certainly satellite imagery is a form of remote sensing.

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(Opening Music)

(Linda Greenlaw, Segment Host) Hi, I'm Linda Greenlaw. When fishermen first worked the waters off the New England coast, they were armed with little more than sails, hooks, and a healthy respect for the sea. Success frequently depended more on luck and intuition than anything else. Today, technology has reduced some of the need for luck by providing ways of tracking currents, predicting weather, and to some degree helping to find fish. A lot of this technology depends on the science of remote sensing- the gathering and processing of information from a distance. Beyond fishing, a variety of remote sensing techniques are used to learn more about our weather, forests, oceans, the entire planet. It's a high tech way of investigating our world.

(Music)

(Narrator) The desire to understand our environment begins at a very early age. In the beginning, we were not able to come in direct contact with our world. Undaunted, our eyes and ears sought information to tell us about the remote environment in which we were destined to live. Scientists today continue to learn about our world from remote locations by using a technology that has been become known as "Remote Sensing".

(Janet Campbell, EOS) Remote sensing is obviously from, from the title or the name it's the technology that we use to observe, in our case the earth or the oceans from a distance. Though we're not literally touching what it is we're trying to measure.

(Scott Ollinger, EOS) More specifically, what we tend to think of as remote sensing is using either satellite or aircraft data. It's by no means limited to satellite or aircraft data, but that's probably about 90% of the remote sensing that's actually done.

(Narrator) These distant vantage points enable us to discover and think about our world in ways, which were impossible, just a few decades ago.

(Berrien Moore, Director of EOS) I think what we now have is the ability to measure all of the components, that we have an ability to measure the planet. An oceanographer really didn't have the ability to necessarily measure up higher in the atmosphere other then the ship's mast. They are essentially taking samples from the beneath them. They really weren't in a position to take samples above them. Well, that's changed, that's changed and it's recognized now that, that the remote sensing capabilities from space particularly, have allowed us to make measurements in the other components.

(Scott Ollinger, EOS) I think there's probably a variety of levels at which remote sensing has affected the way scientists study things. And I might even say that I think remote sensing very broadly has affected the way all of us view the earth whether we're scientists or not, in that it really wasn't very long ago in human history anyway that the largest chunk of the earth's surface we could see was the view from the top of the nearest hill. You know we might be able to see a few miles on a clear day, maybe even a hundred miles, but that was it and for 8 thousand years of human civilization, that's what we could see. And so the, the concept that, that people had of the planet they lived on was very limited. It was very limited based on what visually they were able to experience. But with probably initially with the advent of the Apollo mission, when we were able to start looking at the entire globe instead of just what we could see from the nearest hill, suddenly we have this dramatic impression of the planet that we live on that was never before available to- to humans.

(Berrien Moore, Director of EOS) I felt one of the most amazing comments that I heard from one of the Apollo astronauts is when he observed that he could put his thumb over the earth, that when he looked out the window he could cover the earth up with his thumb. And as he thought about that he realized that he was covering up his family, his town, his state, his country, the oceans, the atmosphere- covering up the earth with his thumb. And that gave you, not only a sense of wholeness, but also gave you a sense of it's not all that large. And I think that that has had a very profound affect, that image of the earth floating in the void of space is a very dramatic, the blues and the whites against this black background. I think really changed the way we all thought about the planet.

(Scott Ollinger, EOS) We never had that sense of earth as our home. I think that was probably ironically one of the more valuable contributions of the Apollo Mission. They went to the moon and really focused on the moon. They wanted to get to the moon. In the end one of the more valuable contributions of that mission was not getting to the moon, but was the image of the earth when they turned around and looked back home. That was the first time we had ever seen the earth in its entirety.

(Narrator) Transcending geophysical and political boundaries, these global images have pushed some scientists to look beyond their own traditional methods of studying the earth as individual parts or systems.

(Berrien Moore, Director of EOS) If we look at the history of the study of the earth we see a very discipline specific, a very rich science. We think of meteorology, think of oceanography, think of geology, geophysics, geochemistry. But after all, these things are connected. …And that gives it a whole different character. And we are now trying to put those pieces together.

(Narrator) The increased focus on trying to understand these interconnections has come to be known as Earth System Science. Located in the heart of Northern New England, the institute for the study of Earth, Oceans, and Space, at the University of New Hampshire is one of the world's premiere academic centers for satellite remote sensing. Here at EOS, as it is commonly called, some of the best and brightest minds from many different scientific disciplines have been brought together under the leadership of Director Berrien Moore, one of the founding fathers of Earth System Science.

(Barry Keim, EOS) Earth system science is really to take a holistic view at all the components that go into making up our environment, including humans I might add.

(Janet Campbell, EOS) Think of the way our planet operates, if you make the analogy to the human body for example, we have systems; we have the cardiovascular system, the neurological system, the skeleton, muscle system and so forth. Doctors specialize in each of those systems. Now we have what we like to call holistic medicine that that looks at the whole body.

(Narrator) And like the basic tools that doctors use to diagnose and make better decisions about our health, remote sensors are providing our scientists with important information to achieve a better understanding of our world.

(Berrien Moore, Director of EOS) Remote sensing really allows us to look at everything, almost. We're able to see temperature patterns. We're able to see moisture patterns in the atmosphere, moisture profiles…Obviously we see clouds, we see that on the nightly news. We see terrestrial vegetation. We see the greening of terrestrial vegetation through photosynthesis. We see the seasons. We see sea surface height, as well as sea surface temperature. The height actually gives us some indication of what's happening below. So in some sense we see past the surface…

(Narrator) What has provided us with this new detailed view of the earth are sensors, which enhance our normal vision and extend our view beyond the visible portion of the electromagnetic spectrum.

(Scott Ollinger, EOS) The electromagnetic spectrum is really a continuation of what we perceive as visible light. Visible light comes in a variety of wavelengths that range from red to blue to violet. Electromagnetic radiation is really the, the physical process by which radiation is transferred from one place to another. And it comes not just is visible forms, but it comes in longer wavelengths, which go way beyond what our eyes are sensitive to and also in much shorter wavelengths, like the ultraviolet and even x-rays are just a continuation of electromagnetic radiation.

(Berrien Moore, Director of EOS) What we do now is we use essentially reflected sunlight and - to make our measurements. In either the visible like where we look down at green vegetation or something that's just reflected sunlight. Or even measuring temperature or humidity. We're still using just the sun. The light either being absorbed in different wavelengths and that tells us something about the atmosphere.

(Narrator) Once the sensor measures the energy reflected or emitted by the earth's surface, it is sent back to earth in the form of numbers. Those numbers are converted by using mathematical equations called algorithms to represent a specific energy signature.

These energy signatures can then be used to infer concrete objects, qualities and features of the Earth's surface.

But we didn't get here overnight… It took the efforts of Robert Goddard, the father of modern Rocketry, to really get things off the ground. As a teenager, Goddard, a Massachusetts native, dreamed of creating a device that could travel beyond the earth's atmosphere into the void of space. Before Goddard, the thought of a rocket propelling itself in the vacuum of space seemed impossibility.

In 1920, The New York Times wrote an editorial in response to an article Goddard had written. It reproachably claimed "he seems to lack the knowledge ladled out daily in high schools". Goddard responded to his critics: "Every vision is a joke until the first man accomplishes it; once realized it becomes common place."

Three days before the Apollo 11 astronauts first stepped on the moon in 1969; the Times wrote a correction to their 1920 editorial, noting that they regretted their error. A lot of progress has been made since Goddard's time.
By the time Landstat 1 – The first satellite dedicated to the study of Earth's natural resources - was launched in 1972, the value of Satellites had become clear.

But taking measurements is only the first part of the picture. Before these measurements can be applied they are typically assembled and processed using sophisticated computer models. Often these computer models are then taken one step further and placed into a Geographic Information System or GIS as it is commonly called.

(Lesley Ann Dupigny-Giroux, UVM-Dept of Geography) GIS stands for Geographic Information Systems. It's been a technology that has been in the making for the last 50 years or so. It originated in Canada and it represents the combination of a series of disciplines in terms of some of the techniques, tools, methodologies that have been used traditionally in fields like geography, mathematics, surveying, things like that.

(Scott Ollinger, EOS) Fundamentally the relationship between remote sensing and GIS, remote sensing is very similar to GIS. But if all you do is take a picture of the surface of the earth, that picture on it's own doesn't tell you where on the earth that picture is from. So you might see individual features without knowing specifically where they're located. Where GIS comes in is actually treating that picture not just as an image, but as an actual map. So you have coordinates associated with all of the features on the image that allow you to overlay the remote sensing image with other computer generated maps, so that you can overlay features from a given point on the ground with other attributes for that same point on the ground**.**

(Narrator) The end product is called a data layer. Which can take on many visual forms depending on the need of the user. Sometimes it is in the form of a simple graph. Sometimes the form of a map. And sometimes a complex animated series. A more intricate picture is now painted. It allows us to see how truly dynamic and interconnected these systems are and how different systems impact and influence one another. As a result of all this high tech firepower scientists are finding that something happening on one end of the world, may have a connection to an event in a completely different part of the world.
This is called Teleconnections.

(Barry Keim, NH State Climatologist) The whole concept of what we call teleconnections is a very new, young science and prior to the '82, '83 El Nino, people really didn't think very much about teleconnections. What a teleconnection really is, is just associations between regions. One region does this and then it causes problems that pop up in a host of other regions that are predictable. Before the '82, '83 El Nino this concept was really not thought of that much. But during the '82 El Nino was so severe and got so much attention and people finally started noticing, wow, we've got this unusual thing going on down in the Pacific and all these weird anomalies are popping up all over the globe regarding the weather. And it's only since then that science has advanced. So when the '97, '98 El Nino finally did come we were much better prepared and we were basically able to test a lot of the hypotheses that were put forth prior. Cause you know basically we had one sample. We had the '82, '83 El Nino and we were making all these wild speculations. But then the '97, '98 El Nino actually enabled us to, to verify a lot of the predictions. But now we have sort of a sample of two, which isn't a whole lot. But the coherence between those two was pretty amazing.

(Narrator) Thanks to the oceanic and atmospheric changes the Topex/Poseidon satellite and Toga buoy array recorded in early 1997, the 97' 98' El Niño was the earliest ever detected. By July of 1997, a full six months in advance, scientist were reliably predicting that the winter over the US would be a very unusual one. But there was one impact they did not anticipate….

(Barry Keim, EOS) What remote sensing has enabled us to do is to be able to see large scale systems, see where the weather systems are, where the funnel boundaries are located, where it's clear, where is it raining. So that's added a whole new dimension to weather forecasting and clearly has made it much much more accurate.

(Lou McNally, WMTW Channel 8) Winter storm warning for ice – in the good old days we would call this an ice storm warning, but we've changed the vocabulary, so officially it's a winter storm warning and I'll put in for ice.

(Lesley Ann Dupigny-Giroux, Vermont State Climatologist) Icing events tend to be perhaps the most difficult for forecasters to predict correctly because it depends on, to a large extent on the thickness of that cold pool.

(Channel 8 Weather Clip)The situation is getting worse, at 6 o'clock Central Maine Power estimated 205,000 customers were without power. I just got off the phone with them, that number's now up to 220,000. This storm is so overwhelming; the utility crews can barely keep up.

(Neil Lamson, Vermont Ice Storm Recovery Coordinator) We knew there was gonna be a storm coming. But nobody knew the magnitude of the storm. We've all had seen freezing rain and sleet and snow. I mean it's New England.

(Bill Frament, Mapping Specialist-USDA Forest Service) Well the ice storm kind of took me by surprise, we knew there was a large weather event that was occurring. But we didn't really realize what the impact of that damage was until a few days later.

(Tom Luther, GIS Specialist-USDA Forest Service) **…** I was planning a ski vacation at the time, so I was getting ready to head to Vermont to do some swishing.

(Narrator) On January 5th of 1998 a devastating ice storm battered Northern New England, New York and Canada.

(Tom Luther, GIS Specialist-USDA Forest Service) I was struck by the ice storm in terms of the magnitude of the damage.

(Bill Frament, Mapping Specialist-USDA Forest Service) I can remember seeing some of the images that I was looking at on different websites and just amazed because powerlines were drooped down to the ground surrounding cars. Trees were just snapped off in people's front yards. Just- it just looked a war zone. It was incredible.

(Chris Casey, Silverculturist-USDA Forest Service) You'd find yourself tuning in to find out what you didn't learn at work by watching CNN or watching the weather channel or our local news and I was just kind of amazed at how day after day the scope of the problem seemed to grow and grow and impact people's lives in ways that I didn't think of initially. But I think in time it all became very clear to us here in New England that this was a pretty major event and it was going to affect our lives in many, many different ways.

(Narrator) The storm stalled for 6 days. Brutalizing parts of Vermont, New Hampshire, Maine, Northern New York and Canada. In the wake of the storm's onslaught 43 people would lose their lives, over a million and a half people would go without heat and electricity – in some cases for weeks. The economic toll would grow in excess of a billion dollars. But the ordeal was not limited to mankind. The storm decimated the trees in its path. In the end, over 17 <u>million</u> acres of Forestland would be affected.

(Bill Frament, Mapping Specialist-USDA Forest Service) Well, remote sensing really gave us the ability to collect a lot of information very quickly, and to get some estimates out very quickly, where we couldn't have done that on the ground – we just didn't have the time to visit all the different areas that had been damaged, or probably the accessibility to get into some of these areas.

(Neil Lamson, Vermont Ice Storm Recovery Coordinator) The thing that we take for granted are roads, are trails that we can walk on, or we can get an ATV and, or a snowmachine and move considerable distances with ease. I mean this is a settled country, you know. I mean, we can move around very easily, but when the roads become impassable, it's a shock to us because they're normally passable.

(Narrator) Neil Lamson, now retired, worked for the USDA Forest Service as a Silviculturist and was the Ice Storm recovery coordinator for Vermont.

(Neil Lamson, Vermont Ice Storm Recovery Coordinator) We were aware that the storm was causing a lot of ice to build up. We could see that the trees were bending, an occasional limb was breaking, but by Thursday evening as the ice kept building and building and we had about 2 inches then of ice on the twigs and branches, everything. Then the weight started breaking branches and as one of our neighbors said, it sounded like World War II. She was quite accurate. I mean it was like gun shots going off all over and it was, it was just rather frightening.

(Lesley Ann Dupigny-Giroux, Vermont State Climatologist) What was extraordinary was the, the accumulations on the ground and certain parts we were up to 3 inches worth of ice on the ground. And that was the part that was a little bit different. How do you walk or slide on 3 inches worth of ice?

(Bob Dyk, Channel 8 News Clip) Take a look at this twig here and take a look at the amount of ice that has accumulated on it. That is a lot of ice that is a lot of weight to bear.

(Tom Luther, GIS Specialist-USDA Forest Service) researchers at the University of Vermont did some study on the ice accumulation on trees and they found some trees that had so much ice on them that they likened it to a 150 pound man wearing an 8 ton suit. Which is pretty amazing that the trees where still up right.

(Narrator) Tom Luther is the GIS specialist at the State and Private Forestry branch of the USDA Forest Service, in Durham, New Hampshire. Along with Bill Frament and others at the Forest Service, he serves on the front line, providing crucial information about the health of the Northeastern forest.

(Tom Luther, GIS Specialist-USDA Forest Service) I was aware that we were going to be called into service pretty quickly. I canceled my ski vacation and I said let's get ready. That- the maps are gonna start coming in and we're gonna need to spend some time, some long hours preparing this data to get it into the hands of the folks that need to go to Congress with it.

(Neil Lamson, Vermont Ice Storm Recovery Coordinator) It was very much of a sense of urgency because we were- by then there was plenty of publicity, that there was an ice storm, that millions of people were impacted by the storm and we knew that our job would be to consolidate the reports that came in from the states as to the extent of the damage to the forest land.

(Tom Luther, GIS Specialist-USDA Forest Service) So we immediately sent folks up in the air to do aerial survey and what that involves is a person literally flying along in an aircraft looking out the side, the aircraft with a topographic map on their lap and physically sketching in areas that appear damaged from the air.

(Narrator) Aerial photography and aerial sketchmapping still remain one of the standard remote sensing staples for assessing the forests. Serving as both a highly skilled sketch mapper and remote sensing specialist, Bill Frament's knowledge and experience served as a guide through this crisis.

(Bill Frament, Mapping Specialist-USDA Forest Service) If you look down in there, you can see some of the birch, that are tipped over, that are kind of crooked over, Straight down below us here. All this area in here was hit by ice damage and it looks like they've been doing some logging to recover some of the wood that's been damaged. And as I'm flying along, I'm trying to keep track of where I'm at on the map, which is the biggest problem.

(Pilot) Of course, my job as a chauffeur is a little bit different than Bill's job. We have to set a up a parallel flight path, generally that goes over the particular areas that we're looking for and I have to maintain that flight path as well as terrain clearance. And occasionally we also get an opportunity to point out damage since we may see it ahead of when the observer in the back sees it. Gives them a little heads up.

(Bill Frament, Mapping Specialist-USDA Forest Service) The challenges that the storm really brought to me were the ability to try to find some one type of remote sensing system that would do it all and there isn't one out there. We have satellite imagery, but the resolution wasn't good enough to allow us to be able to see the light and moderate damage. Aerial photography was really too costly to take over such a large area and then even if we could afford to take it, it would take years just to process those images and to interpret that data and to be able to get a final product from it. So we fell back to our good old aerial sketch mapping, which we've been doing for over 50 years. It's a really low cost, low-tech way of doing things. But it really gives us the ability to collect information rapidly and cost effectively and to get a, you know, a damage estimate out fairly quickly.

(Narrator) The sketchmappers' eyes are the sensors that measure the damage to the forest. This information is traced on to the map in the form of a polygon.

(Bill Frament, Mapping Specialist-USDA Forest Service) Once that sketch map mission is completed we land the aircraft. We bring this information into our G.I.S. specialist. He puts the maps onto the digitizing tablet and digitizes that information and puts it into a geographic information system.

(Tom Luther, GIS Specialist-USDA Forest Service) Well if the sketch mapper has done a good job in the aircraft all the areas are closed polygons on the map and they all have a code for severity and pattern. And at that point I just wipe off the coffee stains and put it on the digitizing tablet and begin the process of manually digitizing the data.

(Narrator) This digitized information is entered into a computer and stored in a GIS system. Once entered it becomes a data layer.

(Tom Luther, GIS Specialist-USDA Forest Service) A data layer is a digital form of data that has that geographic component, that spatial component that lays over the landscape and we call them layers because GIS allows us to analyze data by stacking it on top of one another.

(Narrator) Individual data layers are selected based on a particular user's needs and then added together to make a map.

(Chris Casey, Silverculturist-USDA Forest Service) So we can ask all sorts of what ifs from having that information and creating different map layers and different combinations of layers. That's one of the strength's of GIS, asking those what if questions or the so what questions. It's especially suited for that and it will do it very, very quickly.

(Neil Lamson, Vermont Ice Storm Recovery Coordinator) That tool of making maps, which we call G.I.S. is very, very powerful. Every state here in New England and New York all have their G.I.S. coordinators, their experts in this technology and they are the greatest bunch of people to work for because they love the technology and they want to show people the great things that these computers can do and the maps that they can produce. And that was exactly the case with the ice storm.

(Tom Luther, GIS Specialist-USDA Forest Service) G.I.S. has allowed us to do things much more quickly because all the data are in digital form and we're relying on the computing power of a high-end computer to crunch all the numbers for us. In the old days before we were using computers to the extent that we are today, that was all manual calculation either a hand held calculator or before that even on paper with a pencil.

(Chris Casey, Silverculturist-USDA Forest Service) As someone who started out their career making maps, you know with a pencil and paper and using aerial photographs and in fact doing aerial photography with brass plates and pins and so forth, the new technology that we have at our disposal now is, is just incredible and in fact I was amazed and still amazed and pleased at the products that we can get and how fast we can get the products. It's been a very big boost to forest managers and for the whole world.

(Narrator) Because of the extreme extent of the damage, Tom Luther focused on providing his colleagues with the right information to obtain Federal relief funds for the forest.

(Tom Luther, GIS Specialist-USDA Forest Service) Immediately following the ice storm the most immediate need that we had as a natural resource agency was a fairly accurate estimate of the severity of the damage and where the damage occurred and to do that we used the aerial survey data and the G.I.S. to calculate acreage summaries by state and by county. The reason being that we needed to produce some visual aids that our state foresters could use to go to Congress and make the case for relief funds to start the recovery process after the ice storm. The state foresters were quite successful in that they went to Congress and ended up procuring about 48 million dollars for the 4-state area to begin the relief effort.

(Chris Casey, Silverculturist-USDA Forest Service)At least from my opinion things worked well, worked quickly and the money was brought to bear to where it was needed.

(Neil Lamson, Vermont Ice Storm Recovery Coordinator) We actually put information together, packaged it in such a way that it actually made a difference. When you're a career, shall I say bureaucrat, when you're a federal employee, I mean reports and things are just the way of life and many times you never see other then you send it to Washington, nothing ever becomes of it. And you wonder if they even are read sometimes. But that's the life of a bureaucrat. And so when we were, were informed that we had an emergency appropriation that now that this, this help could go to landowners to - and to cities to help with the urban trees, we were just elated. It was because we care about the resource and we care about the people that were impacted by this. And so for once we could put on a white hat and say we're here to help.

(Narrator) Ice storms are not the only storms that put people and resources at risk. A new ocean observing system that incorporates remote sensing technology can help in many diverse ways. On Green Island, a new radar antenna sits and records measurements of ocean currents in the Gulf of Maine. Radar is a Remote Sensing device, which has been in use since the 1930's. CODAR, which stands for Coastal Ocean Dynamics Application Radar, is a new system of land based Radar stations that use high frequency radio waves to map surface currents in real time.

(Neil Pettigrew, Chief Scientist-GoMOOS) CODAR sends out radio waves from an antenna and then it receives radio waves that are scattered back from the surface, from sea surface waves. Now because the sea surface waves are moving and the ocean surface is moving due to ocean currents, the radio wave that is received back at the CODAR site is shifted. And by knowing the shift in frequency we can calculate the sea currents.

(Narrator) In the year 2000, the Gulf of Maine Ocean Observing System or GOMOOS became the first regional oceanic observing system in the nation. CODAR is one of the latest tools in its arsenal.

(Josie Quintrell, Director of Policy & Planning-GoMOOS) GOMOOS is almost brand new. In July, 2001 Doctor Neil Pettigrew up at the University of Maine deployed the first buoys and finished deploying the whole buoy array over that summer. So now we have 10 buoys that are operating around the Gulf of Maine.

(Neil Pettigrew, Chief Scientist-GoMOOS) When I think back to my own experience I like to think of this thing as an adolescent version of artificial intelligence. It's not quite smart enough to stay out of trouble, but when it gets in trouble it knows enough to call home.

(Narrator) This buoy array is the current workhorse of the system. The buoys are in situ devices – some equipped with remote sensors. They relay oceanic and atmospheric conditions of the Gulf of Maine, via cell phone to a computer at the University of Maine. That information, updated hourly, is then posted on the GoMOOS website, where it is available to the public for free. Although unquestionably one of Northern New England's most valuable natural resources; detailed information measuring climatic and oceanic conditions in the Gulf of Maine was frequently incomplete, not easy to locate, delayed in delivery – or not available at all.

(Philip Bogden, CEO-GoMOOS) One thing that everyone agrees about is that there's very little information about the ocean. The ocean is in a sense a black box. As far as day to day activities are concerned we probably have a better understanding of the cosmos thanks to the Hubbell Space Telescope then we do about the ocean, which is right at our doorsteps.

(Narrator) Here at GoMOOS's headquarters in Portland, Maine, Josie Quintrell and Philip Bogden serve as the organization's administrators.

(Philip Bogden, CEO-GoMOOS) GoMOOS is providing a variety of measurements of the ocean and of the atmosphere over the ocean. They have multiple purposes. We have weather data like the weather service. But we also have ocean currents, ocean temperature, ocean color and a variety of measurements from beneath the surface of the ocean. Those can be used to understand climate change. Those can be used to understand fisheries, things that influence fish populations, the Coast Guard can use the measurements to look for a fishing vessel in distress.

(Narrator) Almost weekly, huge oil tankers traveling between Saint John, New Brunswick and Portland, Maine traverse the tricky waters of the Gulf of Maine. Jeff Cockburn is a ship's pilot who guides some of these tankers in all kinds of weather and he is an avid GoMOOS user.

(Jeff Cockburn, Ship's Pilot) So it doesn't take a lot of effort to imagine what the repercussions are of an oil tanker that's carrying upwards of ten million gallons of black oil having a collision or a grounding that would cause a spill in this fishery.

(Narrator) And although most of the users are predicted to be non-scientists, scientists will reap the benefits as well; because in addition to the surface measurements, the GoMOOS buoys take measurements below the surface.

(Josie Quintrell, Director of Policy & Planning-GoMOOS) Well that's where the magic of the whole Gulf of Maine lies is below the water. You know you look out over the Gulf of Maine you just see the surface. But underneath that it's this rich environment full of lots of little critters, algae, phytoplankton, zooplankton and then as we know a rich abundant marine life from fisheries to, to whales.

(Barney Balch, Research Scientist-Bigelow Laboratory) The surface bias that satellites, especially ocean color satellites have is that they see down into what's called the top optical depth of the ocean. Now the optical depth, you say what is an optical depth? If you were to divide the ocean into layers that have certain amounts of illumination, the algae in the ocean typically can live in the top four to five optical depths of the sea, in the Gulf of Maine that would translate to 50 meters, maybe. That would be four to five optical depths. Consequently the satellite only sees maybe the top 30 feet of the ocean and it means that anything happening deeper than that you won't be able to see.

(Narrator) And this is a problem when you are studying phytoplankton. Barney Balch and Collin Roesler are scientists from the Bigelow Laboratory for Ocean Sciences in Boothbay Harbor, Maine. A pioneer institution dedicated to advancing the field of ocean science, Bigelow has a proven track record of looking at the microscopic in order to understand the macroscopic. These microscopic organisms are phytoplankton. They are the beginning of the marine food web. And they serve as a biological pump releasing oxygen and removing carbon dioxide from the atmosphere through the process known as photosynthesis.

(Collin Roesler, Oceanographer-Bigelow Laboratory) Phytoplankton are beautiful. They come in so many shapes and sizes. They have so many different behaviors and every person who studies phytoplankton has their favorite group. Some of them called diatoms have, they live in little glass houses. Some of them are very long and thin, look like needles. Some of them are round pillbox hats shaped. Some form extravagant chains. They have helical shapes, look like corkscrews. Some have spines. They are a particularly lovely group, one of my favorites.

(Janet Campbell, Satellite Oceanographer-EOS) One of my all, all time favorites is the coccolithophore species, elmiliania huxli. It's a round cell that's covered with lacey like platelets that are made of a chalk, chalk, calcium carbonate.

(Barney Balch, Research Scientist-Bigelow Laboratory) They're absolutely exquisitely architectured. I think one of the reasons I'm in this business is looking through a microscope at these is, it just is a marvel that they're as intricate and finely detailed.

(Narrator) But more than visually stunning these tiny plants are currently under intense investigation by the scientific community.

(Collin Roesler, Oceanographer-Bigelow Laboratory) The study of phytoplankton certainly isn't static. We learn more things every day and with each new thing that we learn we gain more questions. Right now I believe that phytoplankton are a pretty hot topic. And in part that's because of the interest in climate change and the interest in the role of carbon dioxide in our climate. And the question as to whether the ocean might provide a buffer system for the excess carbon dioxide that's being released in the atmosphere.

(Janet Campbell, Satellite Oceanographer-EOS) We knew, you know we could measure the CO-2 rising. We didn't understand why it wasn't rising about twice as fast as we thought it should be. If you count up all the fossil fuel burning, you know the petroleum that goes into the air as a result of burning fossil fuels or gasoline in your car, you would predict a rise of CO-2 of about twice what has been measured. So the question was not why was it rising, it was where is the missing carbon?

(Narrator) Remote Sensing has played a key role for the scientists, helping to answer this question.

(Barney Balch, Research Scientist-Bigelow Laboratory) Remote sensing allowed us to see the large-scale patterns of phytoplankton in the ocean, which caused us to reinterpret how we thought this biological pump was running. And because without an idea of how much is there and the time scales over which they vary, you can't possibly appreciate the magnitude of the biological pump, which is pumping man's CO-2 down into the ocean depths. And remote sensing clearly allowed that where as other, it was more difficult with other studies to, to make the connection between the shipboard measurements and the large-scale patterns of algae growth in space and time.

(Collin Roesler, Oceanographer-Bigelow Laboratory) Coccolithophore are a really unique phytoplankton. They have essentially carbonate dinner plates stuck all over that are bodies. They're spectacular looking. When you have blooms in the ocean the water turns milky, milky white or milky green and the importance of the coccoliths is that in that they have calcium carbonate shells on the outside of them is that when they sink they're taking with them an awful lot of carbon. And so for every coccolithophore that sinks compared to a cell that doesn't contain these liths, there's an awful lot more carbon sinking out of the ocean and so our understanding of these particular species is very important to our understanding of the total carbon budget. They are very difficult to detect unless you do it by remote sensing or you happened to have your boat out going right through a bloom.

(Narrator) When the right conditions are present, phytoplankton multiply rapidly, which is called a bloom.
These blooms can stretch over an area greater than 3 times the size of Maine, Vermont and New Hampshire combined. When they die, much of the phytoplankton sink to the bottom of the ocean taking carbon with them. Until the advent of remote sensing the size of these blooms were not fully understood. In 1988, satellite images detected what seemed to be a large coccolithophore bloom appearing in the Gulf of Maine. Both Dr. Campbell and Dr. Balch were present at Bigelow Laboratory when this discovery was made.

(Janet Campbell, Satellite Oceanographer-EOS) I'll tell you the story of the coccolithophore bloom discovery, all right. See if I can make sure I get this right and not take too much credit. The size of the blooms and their timing when they occur, how long they last and how extensive they are was never appreciated until we had satellites that could view these.

(Barney Balch, Research Scientist-Bigelow Laboratory) I was a new faculty member at the University of Miami, which has a very large remote sensing division there and I had come up for the summer and we heard that this feature was out there.

(Janet Campbell, Satellite Oceanographer-EOS) I can remember the day coming into the remote sensing lab at Bigelow and we had a student who's job it was every morning to come in there, turn on the computer, download the satellite image and look to see if the bloom had occurred. I can remember coming in that day and the student was sitting there going, it's here, it's here!!

(Barney Balch, Research Scientist-Bigelow Laboratory) We saw the image and said, this is incredible. We can't possibly let an opportunity like this go by. We've gotta get out there but how? You know typically ship time is orchestrated two years in advance and it's not cheap and you have to go to the funding agency.

(Janet Campbell, Satellite Oceanographer-EOS) But we were pretty confident it was a coccolithophore bloom. So we went to the funding agencies and started arguing, we need to get a crew out there to study this bloom that happens, right.

(Barney Balch, Research Scientist-Bigelow Laboratory) So I, I remember vividly calling up the program manager at the Office of Naval Research and it was Dr. Richard Spinrad and explaining that there was a feature out there that was far none unlike anything we had seen in the Gulf of Maine and boy wouldn't it be nice to get out there and see what it really was. And he said, well it's out of the cycle... But I might be able to spare a little bit of money for you to get some ship time. You'll have to figure out the rest of it. But we'll worry about that later. Just get out there. We left Boothbay Harbor at sundown. Charlie Yentsch was on that cruise. He was the original director of Bigelow Laboratory. I awoke to him coming in to the stateroom at 6 o'clock the next morning saying you've gotta come up and see this. This is unlike anything that you will have ever seen and you know clearing my eyes, going up on deck and low and behold the water was a turquoise color, brilliant turquoise color horizon to horizon. But here we were in the Gulf of Maine where the water usually is the color of my shirt. That's sort of blue. So it was just amazing.

(Narrator) Could phytoplankton and their ability to fix and remove carbon from the atmosphere be part of the solution to global warming?

(Collin Roesler, Oceanographer-Bigelow Laboratory) One thought is that as the concentration of carbon dioxide in the atmosphere increases, more will dissolve in the ocean and phytoplankton will utilize it.

(Janet Campbell, Satellite Oceanographer-EOS) There have been people, who have proposed, that you could, artificially if you will, stimulate phytoplankton blooms that would take up carbon in very large scales and deposit it. One idea would be to fertilize these parts of the ocean with iron.

(Barney Balch, Research Scientist-Bigelow Laboratory) Much of the phytoplankton in the ocean are limited by iron. And that if one could artificially fertilize the ocean with iron, then you could stop the limitation of growth of the phytoplankton and subsequently you'd have lots more plants growing, they'd be fixing lots more CO2 and when they die or consume, that CO2 that was fixed would wind up on the sea floor.

(Janet Campbell, Satellite Oceanographer-EOS) You have no idea what the impact of something like that would be on the food chain, on the whole Eco-system.

(Barney Balch, Research Scientist-Bigelow Laboratory) It is a simple idea, it may seem elegant, but it is fraught with complexity and potential problems.

(Collin Roesler, Oceanographer-Bigelow Laboratory) We're at a really exciting time in Oceanography. In part because we are at the brink of some incredible developments, technological developments. We have the capability of detecting our ocean from space, we have the capability of deploying moorings that can provide us with data on an hourly basis, real time. And that provides us with a resolution in our understanding of the ocean on depth scales, on spatial scales, and on time scales that are really unprecedented. And what that allows us to do, is to be able to understand processes that we understand very well, for example phytoplankton growth and photosynthesis, other processes we understand very well, tidal currents, non-tidal currents. But to understand them on spatial and temporal scales that we've never been able to study them and to more importantly measure biological parameters and physical parameters on the same space and time scales. So therefore we can begin to really ask questions about what controls productivity in the oceans, what are the forces that are controlling them, and finally how our systems may respond.

(Narrator) And so the technology of remote sensing is a tool that allows us, encourages us, to see the bigger picture of the world in which we live.

(Scott Ollinger, EOS) When we're on the ground looking up in the sky we have this sense that the atmosphere is this vast thing that's above us that kind of goes off into space. When we have that impression of the atmosphere, it's really difficult to imagine that what comes out of a tailpipe of our car could really matter all that much because our cars seem so small and the atmosphere seems so large. But when you get up into space and start looking at the atmosphere from space you realize that it really is a very, very thin layer on top of the planet. You might envision if the earth was a basketball, the atmosphere would be something like a layer of moisture if that basketball happened to be damp. You get a good sense of that from space because you can see this thin little sliver of a, of a layer of atmosphere that's enshrouding our planet that we depend on. But looking up from the ground you are never going to get that sense.