SCIENTIFIC AMERICAN FRONTIERS PROGRAM #1404
"Hot Times in Alaska"
AIRDATE: June 15, 2004

Canary in the Coalmine
The Heat Is On
Squirrels in Decline
The Trouble with Shrubs

ALAN ALDA (NARRATION) There's no clearer illustration of Alaska warming up than what you see here -- or rather, what you don't see. Thirty years ago there would have been sea ice right out here on the Arctic Ocean. Today, there's none in sight. We're getting a ride along the coast with Barrow Brower, an Inupiat Eskimo - the native people of Alaska's Arctic coast. We're looking for the lone inhabitant of a small island. Last winter Barrow dragged a cabin out here across the ice for him. BARROW BROWER I think he likes it. He's a lot warmer I guess. And more protected from the bears.

ALAN ALDA (NARRATION) It was a surprise to the locals that after 28 summers living in a tent, George Divoky had not yet been eaten by polar bears. But George is more interested in a different kind of wildlife. Every summer he comes here to Cooper Island to study the Guillemots. Guillemots nest on the island, and catch fish in the Arctic Ocean. This year they're not doing so well.

GEORGE DIVOKY This guy's over 30 days, which means he should look much older than this. But he's been one of the malnourished ones.

ALAN ALDA (NARRATION) Guillemots are quite common around the world, but this must be their strangest colony. George first found them here in 1972, nesting in the remains of ammunition boxes left by the Navy in the 50s. He built up the colony by carefully arranging the bits of wood to form just the right kind of nesting cavities. Starting from about 10 adult pairs, the colony grew to 225 pairs. George's aim was to study the basic biology of the birds, but it turned out his guillemots would tell a story about the impact of changing climate. The story is filled with new insights into nature's reactions to climate change. One critical factor for the guillemots has to do with the vital flights the adult birds take out to sea.

GEORGE DIVOKY One of the problems guillemots have here is that the food source has to be within a flying distance from the colony. Guillemots are not great oceanic flyers like albatross and even puffins, and feed in the near shore,

typically. So they go out maybe 15 to 20 kilometers or so and come back with food.

ALAN ALDA (NARRATION) Life at the extremes of the earth has little room for error. The guillemots arrive at the island as the snow melts in June, lay and hatch their eggs, feed and raise the chicks, and leave to go south by September. They need plenty of high-energy food to be successful, and for this they depend on a small, oily fish called Arctic cod. Arctic cod, in turn, depend on the shelter and food they find under the sea ice. So all the guillemots have to do is fly out to the ice, dive down and grab the cod. It's a great system - so long as you can find the ice.

GEORGE DIVOKY This year with the ice being well off shore and this being open water, large numbers of chicks died in the nest because parents were unable to find food after the pack ice pulled off shore.

ALAN ALDA (NARRATION) George has discovered what the adult birds do when they can't find cod.

GEORGE DIVOKY This is a chick that is around 30 days old. He is one of the lighter chicks on the island for that age. He's almost 290 grams today, which isn't bad. But one of the problems is that since the Arctic cod are gone, parents are having to feed the chicks things like this four-horned sculpin. And sculpin actually can maintain those horns sticking out like that, which makes it very hard for a chick to feed on.

ALAN ALDA (NARRATION) George knows what happened in every nest on the island, every day of every summer, for the last 3 decades. He's tracked 8 successive breeding generations, and he's beginning to see that some adults are better than others at finding cod when there's no ice nearby. Maybe guillemots can adapt to a different climate. He regularly traps adult birds to see how their health varies, along with their chicks.

GEORGE DIVOKY This is a great way to catch a bird that you know is the parent of the chick inside. You're certain that a bird will be walking over these nooses, within the next half hour of so.

ALAN ALDA (NARRATION) The parents soon show up to feed their chick. And our camera caught a rare sight for this year - a lucky chick gobbling down an Arctic cod. If it had been one of those nasty horned sculpin, the chick probably would have ignored it. One of the adults got caught as it left the nest. George's colony has been in steady decline since the 1990s. Its numbers are now down more than third from their peak. He can relate the fortunes of the colony directly to the steady warming that Alaska has experienced in the last three decades. At

first -- in the 1980s -- things went well as the island became snow-free earlier in the year.

GEORGE DIVOKY When the snow-free period opened up here and the ice was just offshore, things were very good for guillemots here, because they had no constraint about the snow melt or the snow accumulation, and they had prey offshore. As the warming continued, and now the snow is melting in May, well before they even want to breed, so even though now they can essentially breed whenever they want in the spring, they can't raise young as successfully because the pack ice has receded from the colony.

ALAN ALDA (NARRATION) Nature's thrown in a new, complicating factor. In the last 2 years puffins - sub-Arctic birds that prefer warm conditions - have been prospecting for nests in the colony. Puffins are aggressive, and this year George counted 10 of them attacking guillemot eggs and chicks. Quite rapid change is underway on Cooper Island, but it's not just local. Summer sea ice now recedes hundreds of miles offshore all along the Siberian and Alaskan coasts, whereas in the 70s it stayed right at the shore line. Of course the impact can't be confined to guillemots. We just happen to know about them, thanks to George's unique study. Many other animals - from whales to polar bears - depend on the Arctic sea ice. And native hunters depend on many of those animals, in turn. They're all vulnerable, but right now nobody can be sure to what extent.

JOHN WALSH The Alaska Range is out there. You can see it just about every day...

ALAN ALDA (NARRATION) Climate change has become literally a hot topic at the University of Alaska, Fairbanks - now a world center for this research. My first stop was with John Walsh, a meteorologist who's a sea ice expert. He showed me what computer simulations - or models - are saying about the future.

JOHN WALSH On this computer we have some computer model output.

ALAN ALDA (NARRATION) Five research groups around the world have developed computer models of the global climate. This display shows what all five combined are predicting for Arctic sea ice. The views look directly down at the North Pole.

JOHN WALSH The winter coverage is over on the left. Summer coverage is over on the right. And there's a calendar ticking away through the next century. It's at 2055 right now. You'll notice the summer sea ice essentially vanishes by the end of the century.

ALAN ALDA (NARRATION) Disappearing ice is one reason the top of the planet is warming more than lower latitudes. The white Arctic ice is a global cooling system -- it reflects the sun's heat into space. But dark, open water absorbs heat. This is self-reinforcing - ice melts, it gets warmer, so more ice melts, and so on.

JOHN WALSH You're creating a much darker surface where the ice retreats. That darker surface is able to absorb a lot more sunlight. It's much less reflective. So there's an extra gain in the polar regions. It's a gain that the tropics do not have...

ALAN ALDA Oh, because they're already absorbing the heat.

JOHN WALSH Exactly. Yes.

ALAN ALDA And here you were reflecting the heat back. So the change is going to be much more pronounced.

ALAN ALDA (NARRATION) Alaska has warmed up about 4 degrees Fahrenheit on average over the last 150 years -- glaciers really are melting. We're going to spend most of the program with scientists looking at many remarkable effects of warming - from guillemots to glaciers. But why Alaska -- and the earth as a whole - are warming is addressed not by field science, but by the same computer climate models that produced the sea ice predictions. The models say it's caused by greenhouse gases, like CO2, that humans have added to the atmosphere for the last 200 years. This is politically controversial, of course -- but no longer, scientifically.

GUNTER WELLER Many people have questioned, you know, so how reliable are these models? Climate is driven by many different factors, including natural variability -- for example, the energy that comes from the sun, the so-called solar constant -- but also by carbon dioxide. So the models have attempted here to model the climate only using natural parameters. And you can see that in recent years, they've done fairly poorly. This is the observed record in black here. That's the observed temperature. You see that it's gone up. For the natural, in recent years, the computer ensembles, the computer runs don't do very well. If you only use the greenhouse effect, anthropogenic factors, manmade influences, then in this region here, the models do very poorly. You know you can see the color graphs don't coincide with the observed. But if you combine both, and that's the critical issue, then they do very well, and then this gives you some confidence that projections in the future are also probably not all that bad.

ALAN ALDA We're always ready to say, Well, maybe this is a 20,000 year cycle that hasn't really been observed before, and we got through this, maybe we got

through this before, and we'll get through it again, and it's really not going to be affected by what people do. How would you answer that?

GUNTER WELLER You bring up a very good point. Because there are all kinds of cycles, including Ice Ages. Remember every 100,000 years or so we've had an Ice Age, and then that was followed by a warm period. At the present we are in a warm period, and by rights -- the warm periods are only short, 10,000 years or so, compared with 100,000 for an Ice Age -- and we should move into another Ice Age. But I think, and I think the scientific community is behind this idea, that mankind, humanity has begun to interfere with these natural cycles, and instead of moving into the Ice Age, we'll continue this warm interglacial.

ALAN ALDA (NARRATION) It was over the 10,000 years of the current warm interglacial that the distinctive natural landscapes of the north emerged - including the huge boreal forest, or taiga, that's about a third of the earth's entire forested area. We're going to see that great change is now coming to these regions, with consequences for grizzlies and salmon and all the other inhabitants of the north, people included, that we cannot yet predict. We're in the St. Elias Mountains which run between southern Alaska and Canada. This region has a vast, 600-mile stretch of mountain ranges that's sometimes thought of as North America's Himalayas. In front of us is part of Jeffries Glacier, an immense river of snow and ice that's sliding gradually down into the valley.

PAUL CLAUS Ready to roll? Looks like a beautiful day.

ANTHONY ARENDT Yeah. Looks great.

ALAN ALDA (NARRATION) Today, Anthony Arendt and Paul Claus are going glacier flying. PAUL CLAUS Are you good to go? ANTHONY ARENDT Yup. PAUL CLAUS Power's on. Everybody's clear?

ANTHONY ARENDT OK, the gyro is zeroed and we're ready for takeoff.

ALAN ALDA (NARRATION) They're flying out of the strip at Paul's remote hunting lodge. He's an expert bush pilot, who's just started working with the glacier group from the University of Alaska, Fairbanks. They head over to Jeffries Glacier, about 40 miles away and 6,000 feet up. These mountains have some of the largest glaciers in the world. That's because the snow and ice are built up by constant storms coming in from the Pacific Ocean just to the south. For the last 10 years the Fairbanks group has been keeping track of a hundred representative glaciers in Alaska and Canada. They do it with precision flying. Year after year, they've flown the same tracks down the glaciers, bouncing a laser altimeter off the surface as they go. They end up with the exact heights of the glaciers, accurate to within about 12 inches.

ANTHONY ARENDT I'll start logging right when you cross the pass.

ALAN ALDA (NARRATION) Paul banks the plane round to the center line of the glacier, while Anthony prepares to log the plane's position in relation to GPS satellites, along with its exact height above the glacier.

ANTHONY ARENDT OK, laser's in range right now, 200 meters. Looking good. And we're logging. 50 meters. 25 meters. It looks good. We'll just fly right down the center line.

PAUL CLAUS Alright.

ANTHONY ARENDT 50 meters.

ALAN ALDA (NARRATION) They also plot the terminus point in the valley where the glacier transforms into a river.

ANTHONY ARENDT Pretty distinct terminus on this one.

PAUL CLAUS Oh, I guess. Ice ends right now.

ANTHONY ARENDT Okay.

ALAN ALDA (NARRATION) Back at the lab there's a lot of number crunching to come up with the latest height contours of each of their hundred glaciers.

KEITH ECHELMEYER This is our glaciology lab …

ALAN ALDA (NARRATION) Keith Echelmeyer started the glacier project, and used to do all the precision flying himself. They found that, compared to the maps of 50 years ago, the glaciers have shrunk dramatically. And that's not all.

ALAN ALDA Is it really accelerating? What do you mean, accelerating?

BY VALENTINE We find that, on average, every year, that the glaciers are thinning by a half a meter. Every year.

ALAN ALDA Every year.

BY VALENTINE So. You know. So...

ALAN ALDA You mean, from the '50s up through the '90s every year they lost an average of a half a meter.

BY VALENTINE Half a meter.

ALAN ALDA Wow.

BY VALENTINE Then, if you look at the period from the early 1990s to 2000, 2002, that rate goes up to 1.8 meters per year. So nearly two meters every year of ice is lost on average, over the entire surface of the glacier.

ALAN ALDA So that really is zipping ahead, isn't it?

KEITH ECHELMEYER Oh, it's zipping ahead, really a lot. And if that continues in the future, that's what I was saying, a lot of these glaciers won't be here.

ALAN ALDA (NARRATION) The findings translate into staggering volumes of water added to the oceans - 900 trillion gallons just from Alaska and western Canada in the last 50 years, enough to raise sea levels by about a quarter of an inch worldwide. Like Alaska's other climate changes, all we can say right now is that whatever's happening is speeding up.

ALAN ALDA Can you tie this acceleration into some human activity that happened at the same time? Or are they independent?

KEITH ECHELMEYER Yeah, we can't do it for sure. And it's not like the industrial revolution started in the '50s or something like that. It's not that clear. But, this could be... it's really interesting. If it's long term, then it means the climate's really doing something.

ALAN ALDA (NARRATION) We're a few miles from Fairbanks, right in the center of the state. We'd be on firm ground here, you'd think.

ALAN ALDA Why does this drop away so steeply on both sides here?

VLADIMIR ROMANOVSKY Because there was a big ice wedge here.

ALAN ALDA There was a lot of ice in there?

VLADIMIR ROMANOVSKY Yeah, yeah.

ALAN ALDA And that melted, and then it eroded?

VLADIMIR ROMANOVSKY Yeah, yeah.

ALAN ALDA (NARRATION) Beneath the boreal forest's lush carpet of mosses and lichens, there's ice - permafrost. Vladimir Romanovsky is keeping a close and fascinated watch on the permafrost, because he may soon see something that hasn't happened here for 8,000 years.

ALAN ALDA So that's it?

VLADIMIR ROMANOVSKY Yes, this is our borehole which goes down 25 meters.

ALAN ALDA (NARRATION) Vladimir maintains a string of permanent boreholes running north to south through the state. Powered by solar cells, they're constantly measuring temperatures underground and in the air, and logging the results.

VLADIMIR ROMANOVSKY So it's a little bit messy wiring here, but it works well.

ALAN ALDA (NARRATION) Once a year Vladimir comes by to download the records.

VLADIMIR ROMANOVSKY So the upper number is 16.9, that's the temperature of the ground surface. And then it's every approximately ten centimeters is depth, and the deeper one, is minus zero point four, is at one meter. And down to...

ALAN ALDA Minus zero point four. That's really close to melting.

VLADIMIR ROMANOVSKY It's warm, yeah. About, approximately the same temperature is going down to fifteen meters. So at fifteen meters, it's about minus zero point seven. And this temperature stay there like this over the year. So upper part, of course, warmer now because it's summer. But at that depth,15 meters, there is practically no seasonal changes. It stays like this and it's slowly warming.

ALAN ALDA (NARRATION) We'll come back to Vladimir in a moment, but first let's take a look right below him. This is the way into a tunnel driven into the hillside underneath the borehole. The entrance has to be refrigerated so as not to damage the permafrost inside.

CHARLES COLLINS OK. Here we go into the tunnel.

ALAN ALDA (NARRATION) The tunnel was built by the Army in the 1960s to develop permafrost excavation methods. It's a great place to see what permafrost is. The forest floor's now about 50 frozen feet above us.

ALAN ALDA Does the permafrost keep going down?

CHARLES COLLINS The permafrost keeps going down. Another... maximum about two hundred, two hundred and fifty feet in this area, depending on the local terrain.

ALAN ALDA So we're right in the middle of it.

CHARLES COLLINS We're right in the middle of the permafrost in this tunnel.

ALAN ALDA (NARRATION) The walls are made of wind-blown silt, bound with ice, that filled up the valley during the hundred thousand years of the last Ice Age. There are ice wedges, formed when surface water drained down and froze. This ice has been here at least since the end of the Ice Age, 10,000 years ago. Then the area became as warm as it's ever been since. But Vladimir has his eye on the future.

ALAN ALDA The concern of scientists is that it'll get worse, it'll get warmer than it was 10,000 years ago.

VLADIMIR ROMANOVSKY Warmer than it was 10,000 years ago.

ALAN ALDA And the reason for that concern is what? Is it that you just see the trend going and you don't see any abatement in it, it's not slowing? How do you know...

VLADIMIR ROMANOVSKY It's actually accelerating, yeah. It's accelerating.

ALAN ALDA It's accelerating. Ah, so, as long as it's accelerating...

VLADIMIR ROMANOVSKY And the scale of changes, of course, is very different. Because the scale of changes in that time, of course we have some kind of...

ALAN ALDA What do you mean, scale of changes?

VLADIMIR ROMANOVSKY Well, ah, the changes in temperature for the last, say, century, and especially for the last twenty, thirty years was very... All changes were very rapid, and if this trend or changes in temperature will continue at the same rate, we actually will cross this threshold in another fifteen years.

ALAN ALDA (NARRATION) If we do cross that threshold, at some point the ancient permafrost will begin to break down. That will introduce a whole new factor into global climate calculations.

CHARLES COLLINS These roots are from grasses that were growing at the surface here, oh about 30,000 years ago, and they're just preserved in the permafrost. So even though they're 30,000 years old they're just very fine organic material just trapped in the permafrost.

ALAN ALDA (NARRATION) The Ice Age roots and sticks never had a chance to decompose - they were just frozen in place. It's a warehouse of organic material that, once thawed, will release the CO2 it's made of.

VLADIMIR ROMANOVSKY If this material will be exposed to warm temperatures, and together with erosion, it could happen very, very rapidly. So all this -- not all, but a pretty significant part of this organic material will turn into CO2.

ALAN ALDA Is that measurable? Can we make a prediction now about what that's liable to do?

VLADIMIR ROMANOVSKY We can estimate. There is estimations of the amount of carbon in the soil in the frozen state. And this estimation show a very significant number, actually it's the largest number -- it's much more than growing vegetation on top. It's much more organic matter here. And compared to CO2 concentration in the atmosphere, it's also comparable numbers. So if all this organic matter will go as CO2, so we can double actually CO2 in the atmosphere.

ALAN ALDA (NARRATION) So thawing permafrost could greatly reinforce the warming of the global climate. We're heading out to the Tanana River flats, again in central Alaska, where we can see what disappearing permafrost looks like. This is 800 square miles of meandering channels, wetlands, and low-lying forest. It's prime moose habitat, too. Since the last Ice Age, there's been permafrost under everything here except the large river channels. At least, there was until about two hundred years ago. Before then, most of the flats would have been forest, growing on a permafrost plateau just above water level. Now about half the area consists of these waterlogged fens, covered in thick floating mats of vegetation. You can see this transformation continuing today in the remaining forest areas. They call them "drunken forests" - collapsing as the ground disappears beneath them.

ALAN ALDA I see a lot of trees tipped over here.

TORRE JORGENSON Yeah, well welcome to the twenty first century in central Alaska, where the ice rich become the poor. And then I've got to present you with a stick. And you need this for, if you punch through the floating mat out here. It's a way to get back out.

ALAN ALDA So, you're serious about that.

TORRE JORGENSON Oh yeah. These trees through here are about 65 years old. So we can see that, from this age structure, that most of this collapse has happened just during the last thirty years. This is where you start using the stick as a life-saving device. And you can feel a little bounce to that mat so you know that we're really floating on water out here.

ALAN ALDA (NARRATION) I'd really prefer some nice, solid permafrost to walk on.

TORRE JORGENSON See this is what happened to the last guy that came out here. He ended up here...

ALAN ALDA (NARRATION) When I made it through the floating buckbean and horsetail, Torre Jorgenson explained that where we were now standing had actually been a wetland fen only a few hundred years ago. It shows that there are natural cycles in the climate, and it's been warm enough here in the past to thaw the permafrost.

TORRE JORGENSON This is old fen peat developed from buckbean and horsetails, so this tells us that this area used to be a fen at one time. So we've gone through a cycle of it being a fen, becoming uplifted into this permafrost plateau, and then becoming forested by birch trees. And now it's starting to degrade again back into fen.

ALAN ALDA (NARRATION) It's now even warmer here than when the area was last a fen. You can see the process of degradation. As the ice in the ground melts, the soil shrinks, so the surface sinks. The trees become waterlogged and die, and eventually the patchwork of sink holes coalesces into one big wetland. Well, I hadn't fallen through the floating mat, so Torre thought he may as well try me out on drilling a permafrost borehole. We're going down below the level where any annual seasonal variations would be seen.

TORRE JORGENSON OK let's take a look right there and extract what we've got inside. OK, so we've got a little core coming out. It's kind of got slop along the outside of it from drilling, but we're gonna clean that off. So look at that. That's all peat running right through there. And then we're getting into the silts. They're all part of this loess deposit. And just look how wet and sticky that is. That's a real good indication that this is already degrading.

ALAN ALDA (NARRATION) Since the area was last a wetland, a couple of hundred years ago, the climate briefly cooled, and this ice was formed. Then a

steady warming - about 4 degrees Fahrenheit so far - began to switch it back to wetland. That's all it takes for the transformation to proceed.

ALAN ALDA If the present trend continues, how much higher would the average temperature be?

TORRE JORGENSON We would anticipate that within 50 to 100 years, that temperatures will increase on order of 3 to 5 degrees centigrade -- so about 5 to 8 degrees Fahrenheit.

ALAN ALDA Well, wait a minute. So from what you're telling me that means that all the permafrost will melt.

ALAN ALDA (NARRATION) The Tanana flats are especially sensitive to change because the land is already relatively warm, thanks to the waters of the nearby Tanana River. If the predictions of warming coming from the computer models are correct, then the future of this area is pretty clear.

ALAN ALDA What's worrying you is the models that suggest that this is going to keep going, this warming. Is that right?

TORRE JORGENSON That's a good interpretation of it, so my initial concern is that this landscape is very sensitive to small changes. So if we add just a one-degree change, we're losing our permafrost in this area. And we're already, have been losing substantial amounts in the last fifty years with just a half a degree or a one-degree change. So imagine what would happen if you add three degrees or five degrees. It's way beyond the capacity for permafrost to exist in this area, so it'll be fairly quickly eliminated.

ALAN ALDA (NARRATION) Alaska has permafrost under 85 percent of its land area. Sensitive parts like the Tanana flats will be first to go, but there could be very large-scale disruption. This is a Canadian projection showing that the permafrost line could move north by several hundred miles during this century, again if those computer predictions of warming are right. Everything that depends on solid foundations - from forests to roads and buildings - will be affected. Now we're going to look at another kind of change. Alaska is a largely pristine land, with rivers, streams and lakes as far as the eye can see. What's happening to them is not a prediction - it's here and now.

DAVE VERBYLA The question is, Where in Alaska is it getting drier? And what Brian's found is -- most places in Alaska, it's getting drier.

ALAN ALDA (NARRATION) Brian Riordon, who's Dave Verbyla's student, has been looking at ten representative areas around the state. He started with government maps produced in the 1950s.

BRIAN RIORDAN What we're attempting to do is look at water bodies across these maps and see how they've changed from the 1950s to the present day.

ALAN ALDA (NARRATION) In the 1950s, lake 405 was 180 acres. Here it is again in a 1980 picture - it's down to 28 acres. It's the same with the surrounding lakes - the outer rings are the 1950s, the inner rings 1980. It seemed like a clear result, but look at the lake at the bottom right. The original photograph the map was based on, shows a patchy wetland at best. The maps were filled with inaccuracies.

BRIAN RIORDAN What that led me to have to do is go through, order all these black and white photographs which we have right here, for each one of these areas, and go through and recreate each one of these water bodies.

ALAN ALDA That sounds like it would take you fifty years to do that. That's a lot of work.

ALAN ALDA (NARRATION) So far Brian has re-traced about 17,000 water bodies, and he's extended the comparison later in time, using recent satellite pictures. Here's lake 405 again. By the year 2000 - outlined in blue - it had shrunk to 10 acres. The startling overall conclusion is that, just in the last 50 years Alaska has lost on average 15 percent of its open water area. At this point we don't really know why, but it's probably a combination of increased evaporation from warming, and drainage away through cracks in degrading permafrost. I'm with Glenn Juday, a leading expert on the boreal forest - which around here is not doing well.

GLENN JUDAY OK now we're entering a sick forest.

ALAN ALDA (NARRATION) The boreal -- or northern -- forest rings the globe in a huge band running through Canada, the US, Russia and Scandinavia. It's about one third of the planet's total forest area, and easily the largest in North America.

ALAN ALDA Is this alive or dead?

GLENN JUDAY This one is alive but it's been attacked by spruce bark beetles. You can see in the lower section here there's pockets of hardened sap. When the wood boring beetles went into the tree, the tree tried to defend itself by flooding those holes with pitch. When the trees are weak, the beetle attacks are more successful.

ALAN ALDA (NARRATION) In recent years, these trees - they're white spruce - have been weakened. Especially heavy winter snow falls have simply overloaded the tops and broken them off. And in summer there are more insects around, just because it's warmer.

ALAN ALDA So that snowfall, that's a natural event that occurs all the time, right?

GLENN JUDAY Yes it can be, but it happens to be associated with warmer winters. But it's the frequency and the magnitude and the intensity of these conditions that is very unusual right now and reflects the strong influence of the climate warming, that it's having on the health of these forests.

ALAN ALDA (NARRATION) Trees contain a history of their lives, in their annual growth rings. During 20 years of study, Glen Juday has drilled thousands of tree cores at Bonanza Creek.

GLENN JUDAY We use this high tech device here to keep everything all solidly in place. You're looking at about, at least a hundred and fifty years worth of growth. We can see that the rate of growth was very rapid in the early years -- big rings. And it slowed down. Well that's pretty typical of most trees, just from the geometry of the growth. And then there's some really narrow rings here in the late twentieth century. Suggesting that it's rate of growth in the last couple of decades was not very good. And in general that's the signal that we find in these trees.

ALAN ALDA Why don't trees grow well in a warm summer? You would think that warmth would make things grow.

GLENN JUDAY What we've discovered is that it's a temperature-induced drought stress.

ALAN ALDA Drought? It's drought, huh?

GLENN JUDAY They run out of water.

ALAN ALDA (NARRATION) So far we've had winter snowfall, insects, summer drought … and now more insects.

GLENN JUDAY Here we go. This is a tree that's being attacked by the spruce budworm, and you can see the tips of the growing points here, where buds used to be. Now repeated episodes of this, enough years in a row, will just kill the tree. The interesting thing here is, the budworm, as far as we know, was never here before. And number two, it's one of these temperature-controlled insects.

ALAN ALDA Where did it come from?

GLENN JUDAY South of here, in Canada, south and east of here. And it was just too cold for it to live here until the last few years.

ALAN ALDA (NARRATION) We've jumped a couple of hundred miles south, to the Copper River valley. Alaskans can still enjoy the abundance of nature that surrounds them, but here it's against a shocking background. On the slopes above, the boreal forest largely consists of dead spruce trees, killed by bark beetles. With a string of warm summers in the 1990s, there was a beetle population explosion. The die-off stretched hundreds of miles through Canada and Alaska - the largest forest insect attack ever recorded on the continent. Glenn Juday has been growing increasingly alarmed at what he's seeing in the boreal forest.

GLENN JUDAY What we're looking at is aspen leaf miner damage. It's called the leaf miner because it makes these tracks by feeding on the green tissue between the outer and lower layers of skeleton tissue. This is another one of those insects that's triggered by warm temperatures and stress on the trees.

ALAN ALDA (NARRATION) This insect also is widespread. The attractive light gray color of the Aspen leaves signifies leaf miner damage, and it's everywhere.

ALAN ALDA Why do we care about the aspen?

GLENN JUDAY The boreal forest in Alaska has only got about four major species. This one has a major insect problem. The white spruce has major insect problems. And paper birch has major insect problems. So that only leaves the black spruce which is not a very productive tree. So if you take four major species and hit the three most productive of them with major insect problems, you've really made a hit to the amount of growth that's taking place in the forest as a whole.

ALAN ALDA (NARRATION) Glenn likes to take visitors to a popular local overlook on this bluff - but not to admire the view. Here's the bluff from below. It's actually a dry grassland -- not usually part of the boreal forest.

GLENN JUDAY We may be looking at the future here, because this environment is so warm, and so dry because of its steepness of slope here.

ALAN ALDA (NARRATION) A little warmer, a little dryer, says Glenn, and the forest will give way to grassland.

GLENN JUDAY You can see, we're just this close to being too warm and too dry for forests to survive.

ALAN ALDA (NARRATION) Will Alaska's - and the world's --- boreal forest turn to grassland? Of course we don't know, but we do know enough to say what would happen if recent trends continue, and those computer climate models are right.

ALAN ALDA What do you think is going to happen to this forest if these temperatures continue to rise?

GLENN JUDAY They're going to slow way down in growth. They're going to be hit by insect attacks that'll be more and more severe. And with a sufficient amount of warming, they won't be able to grow.

ALAN ALDA (NARRATION) We've jumped 250 miles north to the tundra of Alaska's North Slope. Like the boreal forest, there's a ring of tundra around the top of the globe. Tundra simply means "treeless" in Finnish. Thirty years ago, an isolated field station was set up here at Toolik Lake. The aim was to do basic long term research on how the tundra works - the plants and animals, land and water. But like George Divoky and his guillemots, many scientists who come to Toolik have found themselves studying the changing climate, through the lens of their various specialties. Arctic ground squirrels are a good example. They fatten up in the brief summer, then hibernate underground for 8 months of winter. As spring approaches they feed on underground food stores, to be ready for mating just as the snow begins to melt. That's when they emerge above ground once again. Brian Barnes has been studying the ground squirrels around Toolik for 15 years, working out how they achieve this amazing feat of survival. He's an expert on the biology of hibernation, but his studies are also beginning to show what happens when climate changes. Brian and his student, Ryan Long, closely follow the fortunes of about two hundred squirrels. In summer it's easy to keep track of the squirrels - they're partial to carrots. Ryan walks the trap line twice a day, bringing squirrels in for checkups.

RYAN LONG You look familiar.

ALAN ALDA (NARRATION) To see what's going on for most of the year, when the squirrels are underground, they've devised a high-tech solution. This is ground squirrel surgery at the Toolik Field Station. The squirrel's going to get an implant.

BRIAN BARNES Number 939.

ALAN ALDA (NARRATION) It's a data logger that will automatically record the squirrel's body temperature for the next year. Next day the squirrel, fully

recovered, goes back to his burrow system out on the tundra. They'll re-trap him next summer, and read out the temperature records. The records show that the squirrels wake up underground in March, then eat their stored food. The big day comes on May 1, when mating starts above ground. But lately spring conditions on the North Slope have not been what the squirrels expect. Weather patterns in an overall warmer Alaska happen to make spring here colder. BRIAN BARNES The warming of the annual average temperature is really, is accompanied by quite cool and wet and even freezing springs.

ALAN ALDA (NARRATION) Timing is everything in the short Arctic breeding season, and the squirrels' internal clock doesn't work so well now. BRIAN BARNES The ground squirrels are emerging and initiating reproduction. But it continues to snow and plant life is slow to become available, so a lot of the litters have been lost.

ALAN ALDA (NARRATION) Squirrels are a key prey species on the North Slope - food for grizzly bears, eagles, foxes and wolves. Right now we have no idea whether, or how, any of these animals - squirrels or their predators - will adapt to changing conditions. We're in a basement at Fort Wainwright, Fairbanks. On the shelves - 3,000 priceless, high-quality aerial photographs from the 1940s.

KEN TAPE The original photographs were taken as part of the exploration of what is now the National Petroleum Reserve, Alaska.

ALAN ALDA (NARRATION) It's a detailed portrait of the North Slope 60 years ago.

KEN TAPE Alright Ed, if we could just head over to the Itkillik, we'll fly a line running north on the Itkillik.

PILOT OK.

ALAN ALDA (NARRATION) Ken Tape's group is now retracing the steps of the Army reconnaissance crews who took the photographs. Fortunately the crews' meticulous records of their original flight tracks still exist, simplifying the task of getting back to the same places.

KEN TAPE So go ahead and cross all the way over the river. Maybe go a quarter mile past the river, and then head south, altitude about a hundred feet.

ALAN ALDA (NARRATION) The idea is simple - take new pictures of the land, and see what's changed.

KEN TAPE Great if you could, just come to the right a little bit.

ALAN ALDA (NARRATION) Over the last 3 years, Ken's flown thousands of miles, crisscrossing the North Slope and re-photographing the landscape. So far he's got 270 good matchups.

ALAN ALDA This is now, and this is then.

KEN TAPE Yeah, this is 2002. And this is, I think, 1948.

ALAN ALDA Well et me see if I can see what's different here.

ALAN ALDA (NARRATION) At first glance, you might say the vegetation has maybe increased a bit. The researchers wanted to be rigorous about it, so they divided every picture into grid squares about 50 yards long on the ground. Then using convenient landmarks like large rocks, they matched each old and new pair of grid squares, and estimated the vegetation cover. Using this method, it's become clear that the land's now a lot shrubbier.

ALAN ALDA Do you have a percentage of change -- this much percentage more shrubs than we had before?

KEN TAPE There's probably a thirty or forty percent increase in shrubs, which is huge.

ALAN ALDA (NARRATION) Matthew Sturm started the repeat aerial photography project. He's an expert in snow and how it interacts with land. Shrubs and snow may sound like specialized subjects, but to Arctic scientists they are of vital interest. That's because, just like sea ice in summer, snow and shrubs govern how well the Arctic radiates the earth's heat into space in winter. Matthew lives in the forest outside Fairbanks, but his heart's on the treeless tundra.

MATTHEW STURM These are related very closely to the alder that we're seeing increasing on the North Slope. I like these because they kind of remind me of where things might be going up there. They're very large, and while we don't see any quite this large up there, maybe some day we will.

ALAN ALDA (NARRATION) No single result has galvanized Arctic scientists like that of the shrub photography study. It's shown that Alaska really is changing. What we thought was a timeless landscape isn't anymore.

MATTHEW STURM To date we've repeated about 270 photos. They span all of northern Alaska. The photos show, almost every one, some amount of positive change. In other words, in each of the photos we're seeing increased shrubs -- in

some, very dramatic, some other places more modest. But the big finding is, everywhere we look there are more shrubs today then there were 50 years ago.

KEN TAPE In less than one human lifespan, we are witnessing geologic time. I mean, we're witnessing changes in our lifespan that are, I think, dramatic given the fact that we're looking at 50 years. 50 years in geologic time is the blink of an eye, and we don't know how this is going to fit into the big picture, but this is a fairly dramatic change.

ALAN ALDA (NARRATION) Here's why that change is important. Shrubs in winter trap the snow, which insulates the land, so it gets warmer. And if they stick up above the snow, the shrubs also make the land darker, so it reflects less heat. This is a big deal, says Matthew Sturm.

MATTHEW STURM The whole Arctic system will begin to change. The land, the tundra, won't function the same. It will potentially absorb more heat, reflect less sunlight, and that'll feed back into this whole system of warming. So it's the bigger picture really that we're kind of thinking about, because I think humans will be able to adapt to a change from tundra to shrub, and so will many animals. But, as that very large system starts to change, it has both local and global implications.

ALAN ALDA (NARRATION) We're back at Toolik Field Station on the North Slope. For many years, researchers here have been tending some unusual greenhouses. The tundra is by no means barren, as we sometimes think. It's filled with mosses, grasses, flowers, lichens - about 1700 species altogether. The shrubs -- like alder, willow and birch -- are mixed in, but in these harsh conditions they stay low and don't dominate. Toolik scientists tend to do a lot of walking. This is Donie Bret-Harte coming up to the greenhouses. The greenhouse experiment is to see how the tundra reacts to long-term warming. Inside the enclosures it gets a few degrees warmer in the growing season. They also add a little fertilizer, because if the whole landscape does warm up, the soil would release more nutrients. After 15 years, the result is dramatic.

SYNDONIA BRET-HARTE This is tussock tundra that's been warmed and fertilized for fifteen years. And you can see that what's in here is mainly just one species. It's the dwarf birch. But now it's over a meter tall, it's very bushy and it's pretty much out-competed all the other plants.

ALAN ALDA (NARRATION) Warmer conditions happen to favor the shrubs, which then take over. Although it was started long before Matthew Sturm's aerial photography project, this has become the key experiment which explains why the tundra is getting shrubbier. It's because it's getting warmer.

SYNDONIA BRET-HARTE We do know that over the past fifty years, from the repeat air photo studies, that the shrubs have been expanding across the North Slope -- not only birch but also alder and some other shrubs. And so, I can't really tell you the speed with which it might look like this but we think that if the climate was to warm dramatically enough, you would end up with something like this eventually.

ALAN ALDA (NARRATION) We're going to look at one more change that's underway on the tundra. The studies began at Barrow about 30 years ago. Like increasing shrubs or disappearing sea ice, this change also has global implications. In the 1970s, Walt Oechel was measuring CO2 gas on the tundra. Growing plants take in CO2, while decomposing soil gives it off. Cold tundra soils don't decompose much, so historically the Arctic has been a net absorber, or sink, of CO2 from the atmosphere. It's been that way for 10,000 years, and in the 1970s, Walt found that's exactly what was happening. Then 10 years later he did some new measurements.

WALT OECHEL We found to our great surprise that the tundra was already losing carbon dioxide to the atmosphere. So that by the start of these experiments, which was in 1982, the tundra had already warmed and dried enough, that its historic role as a carbon sink had reversed and changed. It was now losing carbon dioxide to the atmosphere. That was totally unexpected.

ALAN ALDA (NARRATION) People had thought that faster plant growth in a warmer Arctic would absorb the extra CO2 from increased soil decomposition, but apparently not. The tundra and boreal forest soils store as much carbon as the entire global atmosphere holds.

WALT OECHEL Together these two systems contain about 450 billion tons of carbon, in the soil systems. So if a significant portion of this were lost to the atmosphere, that would be a huge amplification of the CO2 in the atmosphere.

ALAN ALDA (NARRATION) That in turn could greatly amplify global warming. Walt Oechel is setting up a series of instrument towers to continuously monitor CO2 gas above the tundra. He runs an instrumented plane to check CO2 over large areas. The Russian and Scandinavian Arctic are also now giving off CO2, so he's working with their scientists, too. We have to fully understand this big potential threat to the climate, he says.

WALT OECHEL We know that the tundra now overall is losing carbon to the atmosphere. What's much harder and less certain is how the tundra's going to change over the next 50 or 100 years. And that's really the crucial question.

ALAN ALDA (NARRATION) Alaska and the Arctic are in the grip of change. No scientist can say right now how it will end up, but it's clearly going somewhere new.

MATTHEW STURM This is an Arctic where instead of sea ice existing in the summer we have an open ocean in the Arctic basin; an Arctic with a much, much smaller icecap in Greenland; an Arctic with considerably less permafrost, or permafrost that is not completely frozen in the winter so it has a ground water system; an Arctic with shrubs, rather than tundra. So it's kind of a vision of a different Arctic, one that's warmer, shrubbier, less ice-covered, and consequently not nearly as good at getting rid of earth's heat as the Arctic we know today. We don't really know if that's where the state is at, but that's what people are starting to think about, and trying to understand if that's where things are headed.

ALAN ALDA (NARRATION) We made our program in Alaska, but you can be sure that guillemots, ground squirrels, forests, glaciers and tundra are changing all over the north. Many scientists said to us that the north is the canary in the coal mine - the harbinger of things to come in the rest of the globe. Whether we can do anything about that -- or care to -- is another story entirely.