Jason: Thank you everybody for joining us this evening. My name is Jason Servanek and I'm the Education Outreach Coordinator for the [unclear :08] Research Center and I'd like to thank the Conservatory for hosting us this evening. Just to let everybody in the audience know, there is also a live call that we're broadcasting tonight so the event is broadcast and is available for viewing later. We're not doing any video work, just audio and all the slides are available. Anybody can see that at any time in the future if they'd like. So I'd like to welcome you here this evening. Joel Barker from the School of Earth Science in Ohio State is here tonight and he'll be presenting. He's also a Researcher at the [unclear :43] and Joel has been gracious enough to make a number of presentations to school groups, educators, community members over the last year and a half so thanks for joining us again. He probably has one of the most amazing things to show you that I think the Center has which is kind of a well kept secret. You'll get a chance to see some ancient material this evening. Thanks Joel.

Joel: Thank you Jason and thank you all for coming to the talk tonight. It's a wonderful venue and I hope the talk lives up to the venue. So I'm going to be talking about three million year old polar plants evidenced in the Boreal Forest Ecosystem in the Canadian High Arctic. I chose this slide as the title slide and it [unclear 1:37] at all. There are no plants and that's the environment there now. There are, well there are plants. There's not plants like there used to be and so I'm going to be presenting some data from work that I've done a couple years back showing how we can use this evidence to give us insight into how things used to be in the Arctic and how things might be in the future.

[unclear 2:02] will go all the way up to 82 degrees north on northern [unclear 2:08] Greenland. A satellite view shows a better image of the area we're going to be looking at. It's actually a national park in Canada. From about here northwards there's also a military base just on the northern tip. It's probably best known for this long lake called Lake Haven. It's a large fresh water body north of the arctic circle, about 74km long, 3km wide and upwards of 250 meters deep and because it's such a huge fresh water body, it actually modulates the climate latitude area, so it's the terminating ground for migratory birds, richly diverse in [unclear 2:52]. If you look at this picture well, you can see this area here is dry, there's not a lot of snow there. The [unclear 3:01] on the other side of this chain of mountains there is a lot of snow and that's because these mountains serve as sort of a weather trap for systems coming off the [unclear 3:09]. They raise over these mountains, precipitation falls to the west and on the east side of [unclear 3:16] so it's a polar environment.

Temperatures because of the lake are as I said quite mild, either summer time temperatures so from May to August, this was in 2009 and it really hasn't changed that much average about 4-5 degrees Celsius. In July it gets upwards of 10 degrees with some excursions up into the 20s, so it's a very short growing season, short warm season, but quite significant.

This is what it looks like on the ground. So as is typical for polar desert, they're sparsely vegetated, mostly just mineral soil from frost soils so they're frozen year round, except in sort of [unclear 4:05] vegetation. If you take a step backwards, back in the mountains spanning to the north, and again very sort of unvegetative areas except in the low lying areas where water can collect to get your wetlands where it can be lushly vegetative. The plants you see there, dominated by things like dwarf fire weed, mountain [unclear 4:32], arctic poppy and this is the only tree you see up there, the dwarf willow. It tends to grow to a maximum of centimeter or two off the ground. It spreads out quite extensively laterally and that's an adaptation so that they don't suffer from a lot of wind damage or desecration due to snow fall. So that tends to protect them, but in terms of trees, that's all you get up there.

This white line indicates the tree line. You see just how much farther north we are than the tree line in North America. So you wouldn't expect to find trees there at all. Now before we get too deeply into this, I want to make a distinction, some terminology you'll have to remember. So most people have heard of petrified wood. A show of hands, petrified wood. So this is wood where slow ground water movement, water that is rich in [unclear 5:28] either encased or replaced all the organic matter in wood, whereas mumified, just like what you think with Egyptian mummies, here we just [unclear 5:37]. I have a piece of mummified wood here. Now it is a bit dirty so try not to get it all over yourselves, but it's just like wood we find outside today. There's nothing really amazing about it except for the fact you find it up here where there are no trees, but it's in a mummified state. It's not petrified. There's been no mineral replacement, so this allows us to use many of the techniques people use for temporary treats on this material.

I was up there on a totally unrelated project and I'll cover some of the results later in the talk. What we were looking at was [unclear 6:24] and that probably doesn't make any sense to you now. I'll get to it in a bit, but because we're in a national park, the park wardens who are normally stationed further south, they all go up there in the summer time because that's where they want to be and camp in the park. So around dinner one night, we were talking about things and they asked what we were doing. I said "do you know anything about trees". Not really. We found some up here and he showed me this picture. This is a [unclear 6:55]. These are sizable pieces of wood, these are logs, but nothing is up there now. So how did they get there? What are they? I was immediately interested so I got in a helicopter, flew to this site, got off the helicopter and the pilot told us we had 30 minutes and so we just ran around like crazy trying to grab [unclear 7:15], but grabbed enough samples that we could sort of try to figure out what was there and why it was worth going back so we did go back.

This is sort of typical of what you would see on the site, just wood scattered around, really interesting things about this wood. First of all, that's a piece of spruce and that is not someone's giant finger. That's just your average sized person's finger. You can see they're very narrow trees. That tree is at least 87 years old based on counting the tree rings. So any trees that lived up there didn't put a lot of resources [unclear 7:52]. They were just sort of hanging on, just surviving, which has some interesting implications, which I'll get into in a little bit. In full disclosure, this isn't the only place in the Canadian arctic where you would find trees on the tree line. This is a list of sites where trees have been reported. Most of them sort of stand in the last 5-10 million years how old these pieces of wood are. The oldest is 45 million years old [unclear 8:29]. So people get this wood, they go and determine the age of this wood and those are the results they come up with. It's exceedingly difficult to do that and I'll get to that later as well.

What makes our site unique isn't really the age of it because I'll tell you how we get into the age of it [unclear 8:52]. I apologize for that. We'll get into it a bit later, but the age isn't what makes this site special. In my opinion it's the fact that we're the farthest North, that we are as close to [unclear 9:09] petrified wood. They're not in a mummified state, so that limits the analysis we can do. It's far north and there's evidence the plants were very much under stress in that region because those tree rings are so small. So the idea here is if we've got vegetation with latitude, indicating a path climate, during the [unclear 9:33], if climate were about to change in the arctic, ours I would argue and I have argued unsuccessfully to funding, ours would be the first site to indicate a [unclear 9:46] response to that kind of change because the plants are just on the edge of their survival, any [unclear 9:51] they're going to be most sensitive to, more sensitive than sites further south where they're insulated from climate change because they're in a more modern climate.

So now we get into some graphs that I take from the [unclear 10:09] basically showing that climate change on our planet is nothing new. We have had times in the past where climate has been warmer, it's been colder. So if you look up on the very top graph there, we've got atmosphere carbon dioxide on one graph [unclear 10:33] across the top there and we've got [unclear 10:38] and all that's telling us is the latitude to which ice extended during that ice age as indicated by those blue bars coming down from the top and then the atmospheric CO_2 corresponds to the rest of the squiggly lines and there's multiple avenues of investigation you can go into when you're discussing these sort of things and trying to find evidence of climate change. So you can look at things like boron isotopes. This is a tricky one because boron isotopes don't tell you anything about carbon dioxide directly. What boron tells you is how acidic the water body was that [unclear 11:15] so in this case sea water and how that [unclear 11:19. We've got a lot of CO_2 in the atmosphere, it mixes with water to form an acid, carbonic acid and that [unclear 11:25] something that's just been in the press recently, ocean [unclear 11:29] and that sort of thing. So that happened in the past when CO_2 levels were high in the atmosphere and you can [unclear 11:36] that signal using things like boron isotopes. Things like the [unclear 11:41] as well. Plant have inverse relationship with density [unclear 11:46] leaves and the concentration of CO_2 in the atmosphere. So the more CO_2 there is in the atmosphere, the less [unclear 11:56] so you can look at fossils, yet in abundance of [unclear 12:02] and get an idea of how much CO_2 there was in the atmosphere.

Notice in none of these we're specifically measuring temperature. We're just measuring carbon dioxide in the atmosphere, but as we've been told and as we've learned, carbon dioxide is [unclear 12:22] so does that add up? Well, we go to this graph, this middle one to see if that adds up. You can see on this app we have the ocean temperatures in degrees and Celsius. On this app we have [unclear 12:37] temperature of water and you can see that when we run atmospheric CO_2 both in that top graph and then the [unclear 12;51] from 0-65 million years ago, you can see the concentrations of CO_2 in the atmosphere roughly correlate to temperature. So there seems to be some sort of [unclear 13:05] in that for some sort of correlation in the past and [unclear 13:11] has been proven recently so we're applying these recent findings to the past looking for indicators that that relationship held in the past as well and is does.

So one thing that I'd like to point out here again getting back to a point that climate has always changed [unclear 13:31] so you can look at the [unclear 13:33] upwards of 12 degrees. This is known as the [unclear 13:39]. That's when the first temperatures rose 6 degrees and it took 2,000 years for it to do that and so you might ask why. How did we do that? We're talking about climate change in the future on our planet. We're talking about a change of 3 degrees in the next century, which is incredibly rapid relative to the [unclear 14:02]. Here we attribute, presently we attribute CO_2 in the atmosphere to [unclear 14:10] what happened in the past. We're seeing things sort of trend. What's the explanation for this sort of rise back then and the answer is this is when Pangea, that super continent, when Africa was our next door neighbor. All the continents on the planet were condensed into one super continent named Pangea. Well it started breaking up due to [unclear 14:32], but there was widespread rifting, lots of [unclear 14:36], lots of CO_2 being emitted to the atmosphere. Methane as well and so we did have a CO_2 and Methane enriched atmosphere during this time and we had the highest temperatures that we've seen in the last 65 million years. You can also see we have dips in temperature and these correspond to ice ages.

You can see up here with this first dip, this is when the east end arctic ice sheet started to grow. We start getting some threshold that reached this side where we start getting west end arctic ice sheet growing and then finally at around 2.5 million years ago that's when we started getting ice sheets in Greenland and pervasive sea ice in the Canadian arctic. So it's within this context that we're trying to fit these logs, these pieces of wood that no longer exist. How did they live way above tree lines? How did they get there? How did they live there? How did they survive and what can they tell us about climate?

So everyone's heard of the greenhouse effect. It's actually an amazing thing, the greenhouse effect because it's been here forever and this is why earth is such a good place to live, but as a climatologist, I like the greenhouse effect because you can see the greenhouse effect. This is a sideways shot from the International Space Station through our earth's atmosphere. This is the land surface here and then we've got this red band and then the blue band. So this is the earth's atmosphere and the reason why this is red, that's the tropics here. That's where all the greenhouses are, that's where all the water vapor is. So this is where sunlight is being scattered due to greenhouse [unclear 16:19]. Above that we don't have greenhouse gasses. We have ozone [unclear 16:24] coming in from the sun, but this in a picture is the greenhouse effect. It's in a diagram this greenhouse effect. [unclear 16:39] short wave radiation. Some of it makes it to the earth's surface, eats up the earth's surface, the earth re-radiates this radiation, this longer wave radiation and it's this long wave radiation that interacts with greenhouse gases. Things like carbon dioxide, methane, nitrous oxide and others, water vapor. Trap that red radiation from escaping back into space, causing warming in the troposphere where all these are [unclear 17:09] and that's the greenhouse effect. So by adding more greenhouse gases to the troposphere we're thickening that blanket and increasing the retention of long wave radiation [unclear 17:21].

This is a diagram taken from NASA in the national ocean-graphic demonstration. Up in the top corner there we've got concentrations of carbon dioxide, nitrous oxide, methane and a bunch of [unclear 17:39] things like that just showing the concentration of all of these things have increased over time and continues to increase today. Here is the temperature in the lower stratosphere, which is the atmospheric layer and above the troposphere where all the gases are, which if we're looking for greenhouse gas warming, we expect the troposphere to heat, whereas the troposphere should actually cool if the greenhouse effect is being accentuated. So this is based on measurements taken over the last I guess it would be 35 weeks now. We've got the warm [unclear 18:17] cool colors cooling and you can see broadly speaking in the troposphere, it's warm and interestingly where it's warm the most is when it's situated over industrial centers. In the stratosphere, broadly speaking it's all cooling, which is indicative of the greenhouse effect.

So we'll return to the arctic and look at our field plan. Where I showed you those logs with the [unclear 18:50] just here on this river terrace and there's just wood sort of scattered all around in front of the glacier. This glacier is retreating as are most glaciers on our planet. How can we tell it's retreating? Well there's a big mound of rubble down here where during the last ice age the glacier advanced enough and pushed all that material in front of it and left it there and it started melting that way. It's also retreating because it's spinning and I've got another picture coming up that shows it better, but you can see that lighter color just around the bend there and it's a darker color above it. That's known as a trim line. That lighter color was just recently exposed material. The darker stuff is material that's been broken down, been weathered and had plants growing on it. This is just a time lapse showing two areas [unclear 19:44] proof that this thing is actually retreating. We see in 1960 the glacier [unclear 19:52] and if you use that right here as a reference, there's a reference, you can see that the end of the glacier has retreated back that much in the [unclear 20:05] 50 years.

This is the trim line I was talking about. You can see it's greatly enhanced from 1960, showing where the glacier is thinning. I want to draw your attention to these features here. What these are, they're stream channels along the side of the glacier so this is where melt water, as snow and ice melts it flows off the side of the glacier and flows into the stream or along the side. Now what this shows is that at some point the glacier was all the way up here and that upper most stream channel represented the stream channel that was in contact with the ice at the time and as the glacier thins, it makes a new stream channel and a new stream channel and is working on a new stream channel today. This is a picture of these stream channels from the ground. This was at one time in the recent past the glacier was about this high up the valley wall and it is progressively down here. Now why is this at all important? Well it's important because glaciers have done the dirty work for us in trying to find the source of this wood [unclear 21:13]. You walk up these stream channels, come up against this space right here with a bunch of wood sticking out. So me and my friends were walking up and wood was getting more and more common. We knew we were getting close and then we came around the corner and there it was. [unclear 21:32] sticking out of the face. If you take a closer look, there are weeds and they're just like weeds we'd find outside today. They're not fossils, they're not rock. They're actually weeds.

Here you have sort of the accumulation of wood, like you would on riverbank after a flood. You get back to the lab and you start looking at the solid [unclear 22:02] even insect, all indicative of something very different during the time that the sediment was laid down that exists in the present. [unclear 22:20] because it looked like it might have been eaten and [unclear 22:25] an animal that could give us a better idea of what was going on and when we're looking at in history. [unclear 22:34] which is an extinct species in time.

Bearberry leaves. This one is interesting because there is actually a bit of chlorophyll in there. [unclear 22:53] alder leaves we never found any alder wood, remnants of a tiny [unclear 22:58] so again showing that it's a very different environment than is there presently. If you get a bit more [unclear 23:09] about things and start chemically looking at soil samples and start looking for degradation [unclear 23:16] and that's what these are. If you look at the ratio between cinnamyl and vanillyl monomers you can get an idea of the composition of the forest based on the fingerprint [unclear 23:30] it left behind and to do that analysis, it turns out that the soil samples sits right in what you'd find in a modern day mixed [unclear 23:38]. So we could go out, take a sample and they would fall within this box. So does this arctic sample. There's no [unclear 23:48] up there now.

You could look at the lignin phenols vegetation index. Pretty much the same sort of thing. It puts it right in the middle of the pine forest as well. We can start looking at the structure of that [unclear 24:03] your sample and you can see a lot of of it is aromatic [unclear 24:09] consequences for how this stuff might behave in the future, which we'll get into in a minute. This stuff doesn't do [unclear 24:17] very well. It would be considered a very low quality nutrient, but there are carbohydrates, lots of them and [unclear 24:26], which means that they're not all closed off and difficult to degrade like aromatics are. This would be considered candy, anything looking to degrade [unclear 24;37] environment. This is easily metabolized [unclear 24:41]

So take an inventory of what we've seen [unclear 24:47] upwards of 87 years old. With leaves, bearberry and [unclear 24:57] alder, thyme, spruce and [unclear 25:01]. Insect identification, which is exceedingly difficult, I don't do it, but I've been told it's exceedingly difficult. We can definitely [unclear 25:09] two species of beetles, but at least six others are in there. We haven't really identified which ones they are and then we got a [unclear 25:17] to look at things and confirmed what we found in the wood and the leaves, but also there is some hemlock nearby and in all the [unclear 25:29] forest with plenty of water available, which is in stark contrast to what's there now.

A very different climate there in the past when this was deposited. It went from something that looked like this to what there is today, but when did it do so? This is sort of the main stock in the research right now. We can explain it very broadly within about two and a half million years. We know that it can't be any younger than 2.5 million years because as you might recall from a map earlier that's when the ice age was there. Things cooled. We had glaciers, we had ice sheets over this region. We couldn't really have trees growing. We don't think it's any older than five million years because there was a tree species in the arctic that is present in a lot of the other sites called Metasequoia. It's closest living relative is the redwood. It was very prolific in [unclear 26:36]. We don't see anything like that in our [unclear 26:41] so we think there wasn't any Metasequoia in there. When they disappeared from this region was about five million years ago. So in looking at being between 2.5-5 million years. It would be really nice to come up with a more concise date, [unclear 26:56] too old. There's a bunch of other techniques we could use, but we didn't really sample properly when we were out there because we didn't really know we had to. [unclear 27:07]

We think we're in this region, which would fall in the Pliocene, which has attracted a lot of scientific interest lately because the Pliocene was the last time in earth's history where atmospheric carbon dioxide levels were similar to what we see today and global temperatures were 3-5 degrees warmer than what we see today, which is what they're forecasting for the next century, well 50 years to a century. So if we're looking for an idea of what the world might look like in the next century, we only need to look back between 2.5-5 million years to get an idea.

Now did anyone [unclear 27:55] in May, 2013? Where for the first time ever, atmosphere carbon dioxide levels topped 400 ppm. That means if you take their sample and analyzed a million particles in there, 400 of them are going to be carbon dioxide. Now you might not have seen it because [unclear 28:21] and that it just appeared. This was just an isolated observation. This has now been passed and the atmosphere of concentration is 400 and a bit over by now, but this is Pliocene. These are Pliocene conditions. So in the Pliocene we had a forested arctic. Temperature was three degrees higher than is was today. What does that mean for the earth going forward? Now this is again taken from the [unclear 28:53] reports where they do a bunch of modeling in the future so this is obviously [unclear 28:59] what temperature is doing that [unclear 29:01] and then they run a bazillion models to try to forecast what the world is going to look like a hundred different conditions. So you can see we have high economic growth, a lot of fossil fuel burning. Our surface warming will rise. Why? Because we put more [unclear 29:20] and then we can just stop what we're doing right now and just keep it constant.

Then you can use that data to start plotting on what our planet is going to look like. So this is a forecast to [unclear 29:44-29:55]. The thing to take away from this is that polar regions, particularly the arctic [unclear 30:02] more than everyone else. So while global temperatures may rise 3-5 degrees, in the arctic you're looking at 7-12 degrees Celsius. So all of a sudden having forests in the arctic with just a 3-4 global change becomes feasible. Now why did this happen? There is a lot of feedback in the arctic to keep it cool. One of them would be albeto. Albeto is just the ratio between incoming solar radiation and what gets reflected back by light surfaces. If you have to split, when we had the recent snow fall, that's albeto. The light surface reflects suddenly back [unclear 30:36]. If you start melting snow, melting ice, melting sea ice, the albeto of polar regions decreases and you start absorbing much more solar radiation. As an increase in temperature, it's going to increase more just because [unclear 30:51]. So polar regions will [unclear 30:56] other regions. So the last time global CO2 was [unclear 31:02] we have today, we have a forested arctic.

What does that mean for animals that currently live up there? We've got, these are just examples of some of the, here's [unclear 31:16] we see up there. All of them supremely adapted to life in a white world and short summers. The fox up there turns totally white. Winter time of course relies on birds that lay their eggs on the ground to get through the summer and the winter. Arctic wolf is of course white. You can imagine [unclear 31:39]. These guys are white of course, but also adapted to a non-treed environment. If you try to walk up to them they'll actually get up on their hind legs and run like you and I would run. The reason why is they can see everything they need to see by getting up. It's only when you get really close that they'll run like [unclear 32:00] and then of course musk ox. Supremely adapted to ice, a cold world. Of course when you shave this guy down he probably looks like a house cat. Thick hooves for breaking up ice. If it warms much, they're going to be in dire straights.

More importantly perhaps is how would a warmer arctic feed in the global arctic system? So this gets into what we went up there originally to look at. Whether or not the arctic was actually emitting carbon dioxide or taking in atmospheric carbon dioxide. Up to this point, research from Alaska suggested that as the arctic warms, in Alaska organic carbon in the soils gets released. The [unclear 32:51] because of the warming temperatures become more active [unclear 32:54] they start breaking down all that matter and producing carbon dioxide and increasing the rate. If there's a lot of water and you don't have a lot of oxygen, then you're producing methane at an increased rate. So we went up to the higher arctic to see if this relationship held true. Up here you've got permafrost which just means that the soil is permanently frozen within a meter of the surface. So in the winter time, the [unclear 33:20] is frozen solid. In the summer time, you start getting surface warmth and you get the development of [unclear 33:26], which is just an area that bubbles, but it usually doesn't go much below a meter. Organic matter gets broken down very slowly in these regions because it's cold. In an arctic tundra, the polar desert is very dry. So there's not a lot of organic matter. Summer time you might get a moderate carbon dioxide coming up just because it's so cold and your active layer isn't that thick, but if you thicken the active layer, you've just got that much more material to work with to break down the soil microbes. They're liking it a lot more because it's warm and so you might get higher CO2 to the atmosphere.

This is important because arctic soil has a whole bunch of organic measurement. A whole bunch. Why? Because it doesn't get broken down. It's so cold that anything, all these plants when they die, they just get incorporated into the soil because they don't get broken down that quickly. We're looking at something in the order of 55.1kg of soil organic carbon per meter squared. Just as a comparison of cultivated soil in Ohio is only about 5.5kg. There's a lot of organic carbon up there to be oxidized and turned to CO2 to contribute to the greenhouse affect [unclear 34:49]

This becomes even more important when you think that you've got [unclear 34:59], like wood that's mummified. That's a lot of organic matter with a potential to be degraded. A publication came out in 2007 when they [unclear 35:08] to the bottom of the [unclear 35:10] and they did a DNA, an examination of the DNA in the the bottom of that icicle. It turned out that it was a [unclear 35:19]. So there's all that organic matter under the green land [unclear 35:27] so there's a lot of organic matter in [unclear 35:29]. So we went up there to measure it. This is what we used [unclear 35:37]. What it measures is it measures CO2 in a parcel of air. It also measures soil temperature, wind direction, humidity, incoming solar radiation, active radiation, all kinds of things. To get an idea of what the flux is, it's a fancy way of saying is CO2 coming from the tundra to the atmosphere, so a source of the greenhouse [unclear 36:02] to the atmosphere or is it absorbing carbon dioxide from the atmosphere, so removing CO2 from the atmosphere.

Now this was no way to worry because the musk ox [unclear 36:16] of course it stands up above the horizon so of course it attracted them like bees. The rabbit, original solar panels were on the ground and they would come and poop all over them. The wolves would actually just like dogs here, peed on our panel and the foxes. Anything we tried to bury or any wire that was exposed, they'd pull it out of the ground and eat the wire. It was very stressful, but we managed to get some data out of it. So again this is what we measured. Whether removing CO2 from the atmosphere by photosynthesis [unclear 36:51] or are we releasing CO2 to the atmosphere by soil respiration, which is [unclear 36:57].

We were there in the summer of 2008, a long time ago. This project just kept going. Trends are still happening, so we were there in July, basically to set it up as [unclear 37:13]. How you can interpret this graph is [unclear 37:16] so this is basically July and then you've got the flux, a negative flux and that means that it's drawing down CO_2 from the atmosphere. Positive flux, a source of CO_2 [unclear 37:30] so negative flux [unclear 37:33] positive flux so a respiration is winning. You can see that generally speaking, it's the same. So generally speaking, it's removing CO_2 from the atmosphere. All we get is a tiny, tiny amount, but still the [unclear 37:50] happening in Alaska, but what is this representative in the entire year specifically when the snow melted? Was there any production of CO_2 over winter that gets trapped under the snow pack and then [unclear 38:05] as it melts? We had to go back there and we might ask why not just leave the flux tower up over winter. We couldn't do that because the temperatures were too cold, which I'll show you in the next graph so we just went up early the next season to try to set it up in the snow. The reason why we couldn't leave it there over winter was because our dingle dogger, which is the most important piece of equipment on that tower had this digital screen that would crack at [unclear 38:31] so you can see this is a substantial part of winter where this thing wouldn't have worked.

We went back and again got there early. We were up there in May and the snow didn't really melt until the end of June. Very excited to see the results. We really wanted to see what happened at snow melt and that's what [unclear 38:53], but the reason why, so you can see this is the snow melting. Basically it is soil temperature in green. You can see that under the soil the course [unclear 39:08] so that's really warm and that's less than a meter down. The purple here is soil moisture so this is the snow pack melting. Beautiful, it would be really nice to know what happened there. The reason why was because there was a little diode that ran from the solar panel to the station that as things warmed, all of the wires sort of relaxed and cracked that diode and so we couldn't charge the station from there to when we got up there to monitor that. [unclear 39:41] really disappointing, but the neat thing about it is we see in the winter there's not much happening. This little derp here is actually just an artifact of the sensor warming up so basically it hovers around zero, but we still [unclear 40:00] we see this trend of it being a [unclear 40:04] small one that slowly decreases toward the end of the season when the leaves start to die [unclear 40:12]. at this point, we went back and it keeps happening so the tundra in this region is a [unclear 40;26] for CO_2, which was amazing to us. It was sort of [unclear 40:33] they found in Alaska but there was hope. Why was it a thing? Well if you [unclear 40:40] flux, you can see that [unclear 40:44] so when we have water photosynthesis, we get a decrease in the flux. Basically that's just photosynthesis so when there's photosynthesis it's drawing that CO_2 from the atmosphere.

Now the neat thing about it is these latitudes in the summer time are at 24 hour summer time so the tundra right now in this region all summer long is a consistent [unclear 41:10] which is big news if you're not a big fan of global warming. We were part of a network. We were up here and we had sort of latitudinal gradient doing the same measurements that we were doing and what you see is that as long as [unclear 41:28] you're consistently a [unclear 41:31] respiration takes over and you become a source so as long as the sun is out, you're drawing [unclear 41:44].

This is just results from [unclear 41:49] lights, can you turn off the lights and you actually do start producing CO_2 associated with plants so we take this as some sort of [unclear 41:59] we've got microbe degrading organic carbon from around [unclear 41:07]. So currently the arctic is a [unclear 42;11] for CO_2, but the arctic is warming. We have evidence that in the past, conditions that are similar to date, we had a forested arctic. Those conditions are forecasted for the next 100 years. What's going to happen in the arctic in the future? We'll continue to function as a sink [unclear 42:35]. We're putting more plants there, more roots there. Are we going to maintain that photosynthesis over that soil respiration or in this [unclear 42:47]. Put more plants there, more leaves there, more photosynthesis going on and we're seeing the greening of the arctic happening already. This is a poor diagram, but if you squint, you can see we've got a purple area fringing the southern arctic and it pops up here as well. What that means is that the trend in photosynthetic activity is monitored through satellites but also this

NBVI which I have to write down what that was, [unclear 43:22] vegetation index, so basically a proxy for leafing. A proxy or photosynthesis is actually happening. When you see purple here, that means that we've got more photosynthesis. We've got more plant life, more photosynthesis happening and you can see the tree line, grass line, shrub line is starting to march north so you're seeing the reforested arctic already.

What does this mean? I think this is an outstanding question. In the arctic warming increased respiration so start breaking down the source of organic matter or will bring in more leaves up there increase photosynthesis so it remains the dominant process. Thank you very much.

Jason: Joel can take questions if anybody has them.

Audience: How do you predict [unclear 44:24]

Joel: The past temperatures?

Audience: Yeah.

Joel: That's a good question. You can look at the oxygen isotopes and that's a direct measurement of temperature so I'll go back to this slide. There we go. You see on the wide axis of the middle graph there you've got that symbol with the ATO. That's the ratio of oxygen isotopes and as an air mass or water cools, it preferentially drops the heavy isotopes and the light isotopes get supported out so you can actually use that ratio as a thermometer. [unclear 45:12] So you have a good idea of what the temperature was [unclear 45:17]. The rest are all sort of proxy data using known carbon dioxide concentrations and then monitoring their forcing on climate and getting the temperature.

Audience: [unclear 45:38] What was your sample?

Joel: These aren't mine. I should point that out. These are from [unclear 45:47] so organisms that will take up those isotopes when they build their shells so you can date them and you can see what temperature they lived in.

Audience: [unclear 46:00] glacier retreats, once that wood is exposed does it just deteriorate or in that climate does it not?

Joel: That's a good question and I mean it does deteriorate. Not as rapidly as here because it's so cold and dry, but as things warm they get moisture up there from [unclear 46:28] air temperatures you expect this stuff to get degraded more quickly and it's pretty young stuff for the soil. Microbes would be doing [unclear 46:38].

Audience: [unclear 46:43]

Joel: The flux state, yes.

Audience: [unclear 46:48]

Joel: Because it's a different system so in Alaska it's a lot more vegetative and the soil tends to be a lot wetter so it's a less dense climate. It is a different climate and so things are warmer so the microbes are happier. You've got water so the microbes are happier and if you have organic matter for them to work on, which you do, you start getting a higher flux rate whereas up here it's drier and colder so the microbes are having to work a lot harder to do what they do.

Audience: [unclear 47:22]

Joel: You're absolutely right and so that was what I consider to be the outstanding question is with change, if you put a [unclear 47:49] higher temperatures will photosynthesis be able to help complete soil restoration to have balance and that's [unclear 48:02].

Jason: Thank you Joel. The program [unclear 48:25] the next program will resume in January with two programs from the planetarium at Ohio State. There's fliers over there. This is actually the fifth in the series program and then we'll have a number of programs for you in the spring that will involve 4H. Thank you for joining us this evening. I think Mark has [unclear 48:46]

Mark: Pardon me just for a minute. Hi, I'm Dr. Mark Miller. I'm the education manager here at [unclear 48:52] conservatory. For those of you who need to get on the road, you can exit straight out this way, make a right and it will go right to the parking lot, but if you have time and you're interested, we're offering a tour of our biomes that will focus on the effect of climate change on plants and the reverse, how plants affect climate change. So if you're interested in that tour, just follow along with us back to the visitor's center where we'll gather and we'll start that tour. That tour will be about 45 minutes. To go on that tour, we do ask that you pay admission to the conservatory and another thing, tonight is the first night of our holiday season and we'll be open until 10 so you can also stay and look at all the lights and our cafe, which has great food, will be open until 9 o'clock. I'll leave that up to you. Thank you and thank you to [unclear 50:01] research for considering us as one of their venues. We're thrilled to have you here. That was a great talk. Thank you.