Cryoseismology with Celeste Labedz
Ologies Podcast
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Oh hey, it's that guy on the train who fell asleep eating a sandwich: Alie Ward, back with another episode of Ologies.

I'm working on this episode while I'm in Chicago, and most of the research for asides was done while staring out a window into 1° weather. A degree. *A* degree. One. I learned just how close you can get to an ancient radiator without getting hospital-grade burns. So for this episode, we're going cold. Glacier quakes. We're gonna get into them.

But first, we'll thank the folks who melt my heart: all the people on Patreon.com/Ologies who are submitting questions and supporting the show; all the folks out there who are wearing Ologies merch from OlogiesMerch.com; everyone who boosts the show by texting links to friends, and tweeting, and 'gramming, and rating and subscribing; and of course for leaving reviews for me to savor like leftover potstickers that you forgot were in the fridge. And I read you a fresh one each week, so thank you to ElizabethAnna for leaving this one. They said:

> *I think this podcast got me into med school? Story time: I recently interviewed for med school and got a little too excited while talking about this podcast in the interview and I saw my interviewer write down "ologies pod?" A few days later I got an email saying they couldn't offer me a spot in the school but then a few days after that I got an email offering me a spot on the waitlist and I like to pretend it's because he got a chance to listen to the podcast and decided to give me a chance. Either way I managed to plug this podcast in my med school interview and I'd say that's a win.*

ElizabethAnna, I hope he hears this, and you get in. What a day maker!

Okay, let's get right into it! Cryoseismology. This is the study of the shaking of glaciers. Ice quakes, y'all! So I'm going to skip the etymology, you'll find out in a minute why, but just know this is not a seismology episode: an episode on earthquakes — a big one, if you will — will happen sometime in the future, but just like a shaker, I can't tell you when. But just know it will be imminent. This one — this is ice quakes. So hold onto your snow pants.

This ologist got her Bachelor's in Physics and Geology from the University of Nebraska at Lincoln and is currently working toward her PhD in Geophysics at Caltech in Pasadena, California. I've been following her on Twitter after approximately one million of you jammed on your caps lock and were like [*as if over a megaphone: WARD, FIND HER, ASK HER OUR QUESTIONS!*] and I gleefully did. Last July, she snapped a photo of herself on a glacier wearing snow pants, and a helmet, and field gear with just one small addition, which was a gauzy blue cape, like that worn by Elsa in *Frozen*. She wrote alongside it:

> *I firmly believe that kids should NOT be taught that girly things & science-y things are mutually exclusive. Therefore, I packed a cape with my field work just to show what Glaciologist Princess Elsa would look like! #TheColdNeverBotheredMeAnyway*

And it started a great, global discussion about glaciers, women in science, and how pop culture can help people see themselves in empowered roles. So I navigated the rough terrain of LA freeways and met up with her at Caltech's famed Seismology Lab, up to the press room where you see all the news footage after an earthquake, and we talked about what a glacier is, why it quakes, how she measures it, why it's important, the biggest glaciers, the prettiest blue in the universe, and how we can feel a little more hopeful in the face of a warming climate. So cozy up to the work and the wisdom of Cryoseismologist Celeste Labedz.

Celeste: It's strange, even being there, I have a hard time believing that those mountain peaks are really there. And that's not just because I'm from Nebraska and I think all mountains are fake.

Alie: [*laughs*] That was going to be one of my first questions! And so, you are a *cryo*-seismologist?

Celeste: Yes, I am a cryoseismologist.

Alie: What does that mean?

Celeste: So the way that I explain it to people is I tell them to take apart the word. So a seismologist is something you might've heard of on TV. After an earthquake they say, "And now we're going live to talk with some seismologists about this." I looked up the etymology once and *seismos* is actually Greek for earthquake. It doesn't have a different meaning, it's just earthquake. Got its own Greek word. And so seismology is the study of earthquakes. And then cryo in front — you may have heard of, like, cryogenically cooled or something — cryo means cold. So when we put those together, we get cold stuff and seismology. So yeah, instead of studying earthquakes and other ground motions in the solid ground, I am studying ice quakes and other motions in the ice.

Alie: Is an ice quake… is that a real thing?

Celeste: Yeah. Ice quakes are real things. They're basically just like earthquakes. In an earthquake you have sliding, some kind of motion. You can picture tectonic plates that you may have seen in seventh grade science moving past each other. And that motion, when it's a little fast, can cause seismic waves that you feel. So that's an earthquake. An ice quake can be caused by a similar thing. You can have little faults inside of a glacier or an ice sheet, or any kind of big mass of ice and you can slide along those faults within the glacier. A glacier can slide against the rock that it's on top of, but you can also get cracks that open up at the ice. Those make ice quakes, too. And then there's other sources of, not ice quakes, but other vibrations in the ice. My research is on the signals that come from flowing water inside of a glacier. Because, you know, if you stand next to a rushing river, it's *loud*. You can imagine the ground vibrating a little bit next to a rushing river.

Aside: Celeste says that the same thing happens inside of glaciers!

Celeste: Meltwater moves through them and when it moves it's loud.

Alie: Oh my gosh. Okay. So now, ice quakes are not a thing that I knew about before *literally* right now. How long have you known about ice quakes?

Celeste: I was interested in seismology since high school. I was in the Science Olympiad competitions that high schoolers can do. [*clip from 1954 film White Christmas: "They're young and they're ambitious."*] So I was on my high school science team and there was an event that was about earthquakes and volcanoes and I was like, "This is the coolest. I'm going to do this. This is great!" Then I didn't get into the ice quake side of it, I didn't start looking at cryoseismology until I got to grad school, actually. I was going to be a *non*-cryoseismologist, a regular seismologist. But then a project was brought to my attention that could take me to a glacier and teach me about motions inside of ice instead of inside of rock, and I was all in.

Alie: Now, you are from Nebraska.

Celeste: Yes.

Alie: They get a lot of quakes or ice over there?

Celeste: No!

Alie: Okay. [*laughs*]

Celeste: Well there is… We get snow every year and it's lovely. But yeah, there is every once in a while, really tiny earthquakes in Nebraska. But no, I did not gain interest from experience in seismology. Wasn't feeling earthquakes as a kid or anything.

Alie: Did you like earth science growing up at all?

Celeste: Oh yeah, absolutely. I always tell people that the explanation for why I am like I am is that I grew up in a science museum.

Alie: Did you really?

Celeste: Yeah, my dad works for the University of Nebraska state museum and he's the collections manager for zoology and botany, so he's just in charge of, like, so many dead animals. [*clip from 1960 film Psycho: "You know, taxidermy."*] So yeah, I kinda grew up in a natural history museum, which leads to a nice introduction to science. So I'm really happy and definitely privileged that I had that opportunity growing up. A lot of our family friends were other scientists working for the museum and stuff.

So I grew up with entomologists, and paleontologists, and parasitologists all around. And I was like, "Oh of course I am one of these people!" And that's very nice. I'm very lucky to have had that experience. I liked geology a lot, my dad took me outside a lot. You'll find that with many geoscientists, all around in geology, geophysics, geochemistry, everything. A lot of folks got into it because they love being outside.

Alie: Oh, you know, that makes sense. I mean, the more that you're out camping or hiking, you see striations in rock, and you see something shiny and it's a quartz or something... Did that happen with you?

Celeste: Yeah, getting outside and seeing geology in place is definitely a way to spark an interest in the geosciences.

Aside: Quick aside: I wondered what other jobs a geoscientist might do, and if you're into earth science, you can study soils, or wells, or earthquakes, or oil, or space rocks. And the median salary is like $80-90 Gs, so if you're like: how can I be outside more? Uh, that way. Bonus: not all of these jobs involve mittens.

Alie: And now when you got this opportunity to start studying on a glacier, you'd never been on a glacier before, right?

Celeste: I'd never… I grew up comfortable with snow. There's lots of snow in Nebraska in the winters. I grew up cross country skiing, I just didn't know it was going to be a job skill later. I had seen glaciers on, like, a family vacation, but I had never been on one, really.

Alie: And this is such a stupid question, but what exactly is a glacier?

Celeste: So, a glacier is basically a big pile of ice, and how they form is: year after year, snow falls in places with high latitudes or high altitudes. If you get enough snow falling that it doesn't melt between years, then it just starts stacking up and stacking up.

Aside: By the by, sea ice is frozen sea water and it's not a glacier. Glaciers only originate on land — I didn't know that! And they're on every continent, except for you, Australia, I'm sorry. But you do have really good coffee, I'm told, and you have koalas. Now, what is the smallest glacier? There's no set rule but glacier scientists are like, "Eh, like maybe 25 acres?" Which is about the size of Adele's estate, [*clip of Adele somewhere outdoors: "I just got here and I think I'm losing signal already."*] in case that's of any help context-wise. And yes, how are they formed? Imagine layers and layers of snow falling on land, kind of like a crêpe cake…

Celeste: And then the pressure from just the snow above it will squish that snow down into nice, clear, solid ice. So after many, many, many years of a lot of snow falling and not all the snow melting, you can end up with a huge pile of ice. So, if you have a more localized mass of ice, that's just a regular glacier. If you have a lot of glaciers that sort of connect together among mountains, that's often called an icefield. And you get even bigger and you're covering up whatever it's on top of completely, then that's an ice sheet. So, like Greenland and Antarctica are ice sheets. Then over time, under its own weight, that ice moves. Glaciers will flow downhill or outward. They're just squishing under their own weight and they're trying to go somewhere.

Aside: To recap: glaciers connecting become icefields, and icefields connecting become ice sheets. And when they crawl, and lurch, and quake, they can boop-dee-doo through all kinds of stuff. Glaciers are just out there, they're doing their thing.

Alie: And like, that's how Half Dome became a half dome, right?

Celeste: Yeah. As glaciers are moving, they will carve out the landscape around them, which is really cool because it leaves some really stunning places. Like, Yosemite was carved by glaciers and it's stunning of course. They leave very characteristic shapes. Glaciers will leave nice U-shaped valleys. So if you're looking at a valley, if it's shaped like a V, then a river carved it, and if it's shaped like a U then a glacier carved it.

Alie: Whoa!

Celeste: Yes, they leave these very characteristic landscapes. They'll have these, kind of, sinuous U-shaped valleys with peaks in between so you can tell when a place was glaciated in the past.

Alie: And what was it like the first time you saw a glacier you were going to work on?

Celeste: It was a little bit hectic because I had gone to Juneau, Alaska with my collaborators, 'cause it's the closest city to where we were going to work. Then we were waiting for the weather to clear, to get a helicopter flight up to this glacier - because that's how you get to a glacier. [*clip of Arnold Schwarzenegger in 1987 film Predator: "Get to the chopper!!"*] You have to get yourselves and a lot of equipment up to a glacier. And we had to wait for the weather to clear, and then once it did they were like, "We gotta go, go, go, in case the clouds come back."

So, yeah, we hauled all of our gear into a helicopter and then we got in the helicopter too. And then they flew us up to the glacier, and then we got up and had to get all the gear out so I wasn't able to stop and appreciate it because there was so much to do. Then once we got all of our gear out and the helicopter left, I remember it left and then it just got really, really, really quiet. And then I was actually able to actually look around and appreciate, like, "Holy moly, I am on the ice and there is *so* much of it."

Alie: How tall was that glacier? Like what kind of elevation?

Celeste: So the glaciers I've worked on are actually not that high up. They're only about a thousand meters in elevation. You can actually… One of the glaciers I've worked at, you can hike there from Juno in a day. Just uphill from Juno airport, you can hike up there. The glacier that I worked on for the first time was a small-ish mountain glacier. So it's about a kilometer-and-a-half wide, six kilometers long, and about 200 meters thick at its thickest. So yeah, if you are standing in the middle of it and look down, you can imagine that there's like two football fields worth of ice just straight down.

Aside: For scale, this glacier near Juno is bigger than Central Park — it's actually closer in size to Golden Gate Park in San Francisco, but there are probably fewer people smoking drugs and making out on it. San Francisco, my birthplace: I love you, I love your vibe. But what is the vibe of working on a glacier?

Alie: Can you walk me through a little bit of what your field work is like? Like, how long are you there and what time are you getting up? Is there coffee? And how many things are you measuring?

Celeste: So I have been very lucky that my fieldwork has been in an area with a little bit of infrastructure. So the Juneau Icefield Research Program is an organization that's been monitoring glaciers outside of Juneau and running a field school for students interested in glaciology. They've been monitoring the area for about 70 years and they have some infrastructure there. They have camps on the rock ridges between glaciers and we get to stay there. It's actually pretty plush living for a glacier. On those we will get up bright and early and there is coffee. Breakfast, they do a lot of the just-add-water pancakes, very good field food.

And yeah, then we go out and do whatever we are doing that day. We take our seismometers, which are, basically, very sensitive motion detectors and they can detect really, really tiny motions that a human could never feel on their own. So we have to take those out from our camp and deploy them on the glacier in strategic spots. Usually burying seismometers is best because then that's very nice and quiet, not as much wind and rain hitting them, and they can just get all the vibrations that they need to get. Then as our experiment wraps up then I have to go back out and pick up the seismometers again.

So then instead of going out and dropping all these seismometers in particular spots, then I'm on the Easter egg hunt to go pick them back up again. That part's a little bit less fun because that involves hauling some seismometers uphill, which is a little bit less fun. But you gotta do what you gotta do. Sometimes we are also making some seismic waves. On my second round of field work, we did some active source seismic surveying, which is making your own seismic waves, which is as fun as it sounds. There are two methods.

The quieter method is hitting a steel plate with a hammer. And the louder method is, essentially, setting off a small, controlled, safe explosion.

Alie: What!! What kind of explosions?

Celeste: Basically, they look like large shotgun shells. They're a little bit bigger than a shotgun shell that you could buy for a hunting rifle. Those shotgun shells are blanks. They just have gunpowder in them, no projectiles, and we put them in… it looks kind of like a sketchy gun. We bury the end in the snow or if you're, you know, doing it in the desert or something then you bury it in the ground and, yeah, then you fire it and it makes a little *foomph* noise [*clip of Hagrid from film Harry Potter: "Poof!"*] because it's underground.

And then that generates some seismic waves that will move through whatever you've put it into. So the ice, for me, or the rock if you're out in the desert doing it, looking for faults or something. And then those seismic waves will bounce off of, say, the base of the glacier or a fault in the ground or something they can bounce off, and then be picked up by your seismometers.

Aside: So, they're shooting things into the ground, they're creating explosions to see how the glacier will react and where fault lines might be. In some cases Celeste and her colleagues are looking at data coming in day by day and seeing how much water is rushing through the glacier, and with other seismometers all the data is stored in a memory chip for later.

Celeste: So yeah, it depends on the kind you're using, but some of them you can live feed them back and some of them you just gotta wait and be surprised.

Alie: Oh, it's like opening up a time capsule!

Celeste: Yeah!

Alie: And now, I don't know if you know this, but the Earth's temperature is getting a little bit warmer, and, um…

Celeste: Amazing.

Alie: Yeah, it's been in the news a little bit.

Celeste: A little bit.

Alie: What is going on with glaciers and with cryoseismology? Are you able to track anything based on what's melting, what's moving, what's shakin'? [*"What's shakin'?"*]

Celeste: Examining what's happening with glaciers under climate change is one of the big reasons I want to be doing cryoseismology. It's another tool that we have to check out what's happening inside of a glacier, and what's happening inside of glacier really matters for what the future of a glacier might be like. So, all around worldwide we are losing ice. There are some glaciers that are getting a little bit larger due to changes in weather patterns in their area, but net, we are losing ice, and we're losing *a lot* of ice. That means a lot of potential changes for the world, and it'd be nice if we could help head off some of those changes with knowledge about what's going to happen.

So things like, as we're losing ice, how much ice are we going to lose? How much is sea level going to rise? And you can keep track of how much meltwater is moving through a

glacier or how much it's cracking off the end and just breaking off into icebergs. You can track those things with seismology. That's one tool you can use to check it out. Glaciers are also a really important water resource for a lot of people around the world. A lot of people who live downhill of glaciated mountain ranges, for example the Himalayas, a lot of people are relying on the glaciers there to provide steady water resources for all of their water needs — for their agriculture, for their drinking water, for their water for hygiene.

Getting an idea of what those glaciers might be doing in the future is really important for making sure those people have those water resources. So it's really important to be keeping an eye on glaciers and understanding exactly what's going on, on the inside and out, so that way we can get better ideas of what they might be doing in the future.

Aside: Her work helps us gauge how much ice we may be losing, how much seawater we may be gaining, and what a toastier earth might mean for people who rely on glaciers for their water. Another reason to keep tabs on glacier quakes and ice hunks is because they can surprise you, which, spoiler, these surprises do not involve a glacier popping out from a couch with your name on a cake.

Celeste: Some glaciers can have what's called 'glacial outburst floods,' which are very scary, and also pretty amazing. So you can get dams of ice, like meltwater will be entering an area, but then the ice is actually blocking it. And then when the ice breaks, all that water is free to go. And those can be *really* big floods that are super sudden. And since you can detect moving water with seismometers, this is potentially a way to check out how we can get people downstream early warning before a flood comes through and washes away their home or something.

Alie: And how big are ice quakes? Do they conform to the same Richter scale? Like is a 7.0 ice quake, like, a crazy huge shaker? How big do these things get?

Celeste: So, ice quakes, you can measure them with similar tools, like magnitude scales for earthquakes, but they usually end up looking a little bit different. Really big ice quakes happen when icebergs calve off the front of a glacier, and sometimes you can get a series, where it's just iceberg after iceberg tumbling [s*ound of icebergs falling fades in, rumbling, huge powerful movements*] and rumbling off the end. And they're all going into the bay.

Really big ones of those happen in places like Greenland, and a huge event like that can be as much energy putout as a magnitude 5 earthquake. But if you're standing right next to it, it doesn't feel like a magnitude 5 earthquake because it's happening over a longer period of time. Whereas an earthquake might be happening in a second or so, it's going to take several minutes for all of those icebergs to do all of their tumbling. So, you can measure them on the same magnitude scales, but it's not necessarily a helpful way for humans to imagine how big they are.

Aside: PS: The Seismology Lab at Caltech is the actual birthplace of the Richter Scale, and we'll definitely get to that when we do seismology. But in general, these ice quakes – or 'cryoseisms,' which they're apparently known as – are low-frequency shakers. Big, but mellow. Kinda like the Bernese Mountain dogs of seismic events, but less hairy.

Also, if you've ever, during a winter cold snap, heard loud booms and thought someone was attacking you with an old-school pirate cannon, you may have heard a frost quake, which is when rain seeps into the ground, the temperatures drop, and then the water in the earth expands and snaps. And you'll know if there's been a frost quake by simply turning on the TV to see breathless coverage of news anchors assuring you that the explosions were not the apocalypse.

Alie: What about movies? How do they get glaciers or glacier quakes right or wrong? Are there any that irk you, or any that you're like, 'good job'?

Celeste: Okay, so I was trying to think if there were any movies that have ice quakes at all, and the closest I could come up with was in the beginning of *The Day After Tomorrow*, when the ice shelf is breaking off right under their station where they're drilling for ice cores [*from The Day After Tomorrow: "What's happening?!" "The whole damn shelf is breaking off, that's what's happening!"*] And that was pretty wild, and maybe if they would've had some seismometers they could have had a little bit more warning that that was coming. [*both laugh*] But yeah, you really do get huge crevasses in glaciers, especially on big ice shelves like Antarctica. But yeah, I don't know, there hasn't been too many ice quakes in movies.

Alie: And I know that you have a history with *Frozen*. When you watched *Frozen*, did you love it because you're like, "That's me. That's my jam."?

Celeste: So, *Frozen* came out before I was studying glaciers at all. I just liked it because I love kid's movies. But now I just saw the stage musical version of *Frozen*, it's in L.A. right now, and I saw it a couple weeks ago with my friend, and it was super awesome, as a glacier person. And I saw *Frozen II* recently with another friend, and Elsa actually went in a glacier, and it was really cool, and oh my gosh! My little glacier heart was pounding. It was great!

Alie: Aww! It melted your ice heart! Now, you took a cape with you…

Celeste: Yes.

Alie: It was a Halloween costume?

Celeste: Yes…

Alie: And you bundled it up in a tiny, tiny, little bundle, put it in your knapsack, and it was the glacier cape photo felt around the world. What was your motivation for that?

Celeste: So, it was actually a silly idea. I think it was my mom's idea originally. After my first round of fieldwork, she saw some of the photos I did and she was like, "Hey, you should take the cape we made for your Halloween costume a few years ago next time you go to a glacier and then take some photos, 'cause wouldn't that be fun?" And I'm like, "Oh, yeah, that would be fun!" There's a lot of cool ways to appreciate ice in media, and movies, and fun stuff, through things like *Frozen*, but there's also a way to scientifically appreciate them. And it's kinda cool that all those different experiences in ice can go together in fun ways.

And it's also a cool way to think about, like, who is a scientist? A scientist for this is a person who is interested in ice, and yeah, that's both me and Princess Elsa. It was a fun

way to make a little statement about what a scientist might look like. And also just a fun reason to wear a cape. 'Cause, you know, I always need more reasons to wear a cape.

Alie: You're wearing one right now!

Aside: She was not wearing a cape, but I was wearing a sweatshirt I think I slept in. Just to be real with you. But the point is, don't judge.

Alie: And that was a really good statement, that to be a scientist, it doesn't mean that you have to eschew certain aspects of femininity or gender. Now, when it comes to your outreach – I know you do a lot of it – what is the most infuriating flimflam that you would like to debunk?

Celeste: So, I get a lot of flimflam from the seismology side of my work, rather than the glacier side of my work. People have a lot of myths about earthquakes, and a lot of those myths aren't intentionally trying to be harmful, a lot of them are from our human brains trying to make patterns. So there are a lot of folks out there who think you can predict earthquakes, and nobody can actually reliably predict earthquakes. And some people think there's things like 'earthquake weather' that will tell you whether it's more likely to have an earthquake, and those don't actually make much of a difference. So I usually have lots of myth-busting to do earthquake-wise. The main one that I have to do with glacier stuff is just like, 'yes, climate change is real.' We are losing ice, we are losing a lot of ice, and we should do something about that.

Alie: Can I ask you Patreon questions?

Celeste: Please do.

Alie: Are you ready?

Celeste: Yes! So psyched!

Alie: Ooohhh, boy! Okay!

Aside: Before your questions: a few words from sponsors who make it possible for us to donate to a charity of the Ologist's choosing each week. This week, Celeste chose the International Association for Geoscience Diversity. The IAGD is a non-profit dedicated to creating access and inclusion for persons with disabilities in the geosciences. They celebrate the diverse abilities of all geoscience students, faculty, and working professionals by fostering student engagement in geoscience career pathways. They are doing awesome stuff. So thanks, Celeste, for choosing them, and thanks to some sponsors of the show, who I may talk about right now.

[*Ad break*]

Alright, onto your burning icequake questions.

Alie: Carl Netzler, more of a comment than a question, just says: Love her!

Celeste: [*gasp*] I'm honored. Thanks, Carl.

Alie: So, Carl, duly noted. Jessie Dragon wants to know: Will there still be quakes when the glaciers disappear? Are the glaciers ever gonna fully disappear?

Celeste: So that's a… big question! And that's one reason why folks are interested, like… Why should we be investigating glaciers right now? What's going to happen to them in the

future? So, we are definitely losing ice, we are definitely losing a lot of ice. It will take a long time, especially our larger piles of ice, like Greenland and Antarctica. There is ice loss there, but it's going to take a while for those to be, ya know, gone-gone. So hopefully, that's not a case that we are facing. There are glaciers with projected death dates already.

Alie: Really?!

Celeste: Yeah. If you go on Wikipedia articles for small glaciers that are well known, like, for example, in Glacier National Park, the articles will say, 'this glacier is estimated to disappear by 2050' or something. So a lot of the glaciers have projected disappearance dates.

Aside: I went to look up a graphic representation and found out that 'glacier mass balance' is the term for how much ice a glacier is putting on versus how much it's losing. Putting on a little snow, some is melting. Let's just say that the graphs for that show a definite global trend downward.

Celeste: Essentially, I would say overall, it's going to be following sort of the same kind of global temperature curve. Which is, uh, really taking an uptick since that good ol' Industrial Revolution. It'd be nice if that could take a little downturn soon, that way we have a chance of preserving some of these glaciers, so we don't have to call Glacier National Park the 'Park Formerly Known as Glacier.'

Aside: Okay, there are roughly 198,000 glaciers in the world, remember, larger than Adele's 25-acre country estate. And Iceland, by the by, is expected to lose all of theirs in the next 200 years. And last summer, in a move that was starkly emotional, they were the first nation to hold a funeral for one of their deceased glaciers, which was called Okjokull. But since *jökull* means 'glacier', they just changed the name to 'Ok.' It hurts.

They put up a memorial on what is now a rocky mountainside with a plaque that read, "This monument is to acknowledge that we know what is happening and what needs to be done. Only you know if we did it." they addressed future visitors. Hopefully that plaque will be buried in ice one day. But kudos, Iceland. A glacier funeral is a power move. It's also goth as hell, if you ask me, a person who has held a funeral for a bug. Now, speaking of the forces that shape us:

Celeste: Topography. So you can still look at it, and if you know a thing or two about it, you can look for those U-shaped valleys that glaciers leave behind. You can still say, "Ah, yes, glaciers were here." And some of the glaciers there are going to be gone in the next couple of decades. Some of the larger ones might take a little longer, but yeah, we could see some of those glaciers go away. And other small mountain glaciers, too, are really at risk.

Alie: Right. God, I hope they don't have to rebrand. For many reasons.

Aside: This next question was asked by first-time question-asker Alexis Delgado, Anne-Sophie Caron, Stephanie Broertjes, Tara McNee, aaandd:

Alie: Mae Merrill wants to know: How do wildlife react to glacier quakes?

Celeste: Ohhh, interesting! I haven't really thought too much about this. So, there's actually not much wildlife on the middle of a glacier because it's not a place with very much food. So when I've done work on glaciers, like I was out in the middle of the Juneau icefield this last summer, we would very rarely see any animals. Occasionally a bird would fly over. We would occasionally find dead birds on the glacier because they would get in and not be able to get out.

Alie: Get in or get out of a glacier?

Celeste: Like, they would start flying onto the glacier and then run out of food out there and end up dying out there. It's kinda sad, but that's the circle of life [*beginning of 'Circle of Life' from the Lion King*] for those birds.

Alie: No pancakes for them.

Celeste: So yeah, there's not a ton of wildlife on the glacier. Oh, one of the coolest things out there is a kind of algae that lives in the snow. It's commonly known as 'watermelon snow,' because it's bright pink.

Alie: Really?!

Celeste: Yeah! So if you go out to a glacier and there's a patch that, like, kinda looks like a murder scene, like there's a reddish, pinkish splotch, it probably wasn't a murder scene. It's probably just watermelon snow. So it's a kind of little algae. And then there's these little, tiny worms, like smaller than a penny, that feed on that algae.

Aside: Ps: I looked this up and it's also called 'pink snow' and 'blood snow,' and yes, there are inch-long black worms in it. You can eat it, but too much might cause gastrointestinal issues, in case you needed one more reason not to eat blood snow peppered with worms.

Celeste: So there is stuff living in the snow. Those little worms are probably concerned when the ice shakes a little bit, but for the most part it wouldn't disturb too much wildlife. Maybe if it was a glacier on the edge of an icefield and had a larger ice quake, maybe a deer or something would look up from its snack and wonder what was going on. But yeah, no, ice quakes don't affect wildlife too terribly much.

Alie: Okay, that's good to know. I just keep thinking about these little disturbed worms. [*Celeste laughs*] They're just like, "I'm trying to munch a melon over here! What's going on down there?" Oh, Maria Hancox wants to know: Where'd she get that cape? I want one.

Celeste: Ohh, I just went to the craft store and bought some glitter tulle fabric. It's like what a tutu is made out of, but you can just buy a couple of yards of it. My mom bought it for me.

Alie: Good to know! [*"Thanks, mom!"*] Okay, Meghan McLean wants to know: Have glacier quakes resulted in the discovery of anything significant in terms of new life forms or fossils? Anything ever pop out of a glacier where you're all like, "'What's that doing there?"

Celeste: Well, I don't know if glacier quakes have helped, but things can be preserved pretty well in ice. So occasionally there have been lost hikers on glaciers in the Alps from, ya know, a hundred years previously. They've gotten buried in the ice and then appeared lower

on the glacier from the motion of the glacier a hundred years after they disappeared. That's pretty wild. A little grim, but yeah, glaciers can preserve things really well. But since there's not much life on a glacier, other than adventurous humans, there's not much in the way of fossils or anything.

Alie: Good to know.

Aside: Patrons Pandora II, Shea, Sara Amish, Cranilation, and Rot also asked about things found in a glacier, and I just have to pipe in that I looked it up. There have been Mount Everest hikers mummified by the ice and later revealed when it melted, and fallen prehistoric warriors from thousands of years ago, and war planes with entire crews, soldiers with unmailed love letters, sacrifice victims, lost lovers in the Alps, and more. Just in case melting glaciers weren't sad enough for you.

Alie: D.B. Narveson wants to know: Where are the largest glaciers by surface area? Those would be Greenland and Antarctica?

Celeste: Yeah, Greenland and Antarctica are both ice sheets. It's kinda like one big glacier, as in it's just one huge, huge pile of ice. But then there's glaciers coming off the side where the ice is oozing out from the edge of the ice sheet. I don't know about what the largest one of those officially is. I know the fastest glacier is called Jakobshavn Isbrae. It's in Greenland. It's moving about 30 meters a day, whereas smaller glaciers, like the ones that I work on, are moving half a meter a day.

Alie: That's still pretty fast for something so big. [*from The Devil Wears Prada, Miranda Priestly: "By all means, move at a glacial pace, you know how that thrills me."*]

Aside: Hey, Meryl Streep from *The Devil Wears Prada,* YOU try moving something that weighs billions and billions of tons 60 to 150 feet a day and tell me that's not impressive, and terrifying, and heart-wrenching.

Alie: Is it weird emotionally to see ice break off and splinter off from a huge glacier? On one hand you've got some great data, but on another it's like, "Ughhh, that's more ice melting."

Celeste: So, icebergs breaking off the end of the glacier is a natural thing. Even healthy glaciers are doing that. So it is something that you can happily enjoy and just enjoy it for the powerful, sort of a gunshot sound of it cracking off the ice. [*rumbling and cracking of falling ice*] You can actually hear it. And then it'll tumble into the water if it's emptying into the ocean or something. So yeah, you can still enjoy that, but then it does remind you that, "Oh, this is happening a little bit more than it used to." It's a weird emotional thing to be up close with glaciers, knowing they're going away.

Alie: Have you seen anything like that? Have you ever seen a huge tumble off, have you been present for that?

Celeste: No, I wish. While on vacation with my family before I knew I was going to be studying glaciers someday, we got to see some icebergs tumble off the edge of a glacier in Alaska. And that was pretty cool, but it wasn't, like, one of the really huge ones. There are great videos online of glacier calving events that are really spectacular.

Aside: That calving event you heard earlier was audio from the documentary *Chasing Ice* and dang, if you like watching glaciers crumble like scones – very loud, rumbling scones – this is the documentary for you, future glaciologists.

Alie: Schmitty Thompson says: I'm a glaciology student, so I have so many questions. Fellow glaciologist. What is the deal with the meteorite impact craters recently found under the Greenland ice sheet through seismic studies?

Celeste: Oh, yeah, this is a really rad case! There's a spot in Greenland that I think somebody was originally just like, "Hey, the topography here looks a little bit funny, let's check it out." And then they figured out that, in what's like Northwestern Greenland, that there was actually a crater below there, and they figured it out. I don't know if they figured it out from seismic or from radar data. One of the good ways to check out what's going on inside of a glacier, like structure-wise, is to shoot radar beams in there and they'll bounce off the bottom and come back. It's kind of the same concept as seismic wave moving, it's just that they're radar waves instead.

So, I don't know if that was discovered via seismic or radar, but yeah, it's pretty rad! They just saw the nice characteristic crater shape below the edge of the Greenland ice sheet. If you zoom into that area on Google Earth, you can kinda see – it's right on the edge of the ice sheet – you can kinda see a little rounded bump on the edge where it's filling up the crater.

Aside: It is bananas, sidenote, that you can just use Google Earth to look at glaciers. I just had a surreal 'how does technology even exist' moment doing that. Also, some fun trivia: this Hiawatha impact crater, and another subsequently found pretty close to it, was discovered by some NASA scientists who were doing a fly-by and just testing their equipment on the way to the Arctic. Imagine making the discovery of a lifetime, seeing a 19-mile wide geological divot in the Earth, when you just meant to be like, [*as if over an old telephone*] "Uhhh, is this thing on? Testing, test- ohh look at that! Holy smokes!"

Alie: Roxanne Parker asks: What's the most valuable or useful piece of technology that you use to conduct your work?

Celeste: A new piece of technology that I just used on my last round of fieldwork and other cryoseismologists are starting to check out, too, is called 'distributed acoustic sensing.' It makes it sound like a microphone, but it's actually really cool. It's essentially tricking a fiber optic cable into thinking it's a bunch of seismometers. You shoot a laser pulse in and then little inhomogeneities in the cable will bounce that laser pulse back, and then if you stretch or smush any bit of the cable from, for example, a seismic wave passing by, then the return times of all those little bounce-backs will change timing. So, a computer sends pulse after pulse after pulse and looks for changes in the reflection that comes back. So that's some wild new technology that means that instead of deploying a lot of seismometers, you can just roll out one cable.

A lot of seismologists in general are really interested in, "How do we use this tech?" Looking at seismology in urban areas is probably where that's going to be coolest because you can use fiber optic cables that are already installed for, like, telecom purposes. You just plug your box in and then check it out.

Aside: When it comes to seismometers - Michelle Lee asked about them - the thing that draws the wavy lines is called a seismograph, and the paper with the wavy lines drawn on it is a seismogram. Which means, Instagram should really be called Insta*graph*. None of this matters. One thing that does matter: How big is a seismometer?

Celeste: Seismometers in the modern day can be really tiny. You can even buy your own tiny seismometer with… it's powered by Raspberry Pi, the little microcomputers. They have seismometers called Raspberry Shakes. [*"Get it??"*] And so if anybody wants to, they can go buy a Raspberry Shake, and you can plug it in, you can feed it into… There's a network of Raspberry Shakes. They're great for, like, education. Teachers will get them for their classrooms and stuff.

Alie: Oh my gosh! DIY seismology. That's amazing!

Celeste: Yeah, it's super cool.

Alie: Okay, I have no idea what this question means, so I'm just going to ask it, and if you don't either then we're going to skip it. No idea what this means. Robin Helton wants to know: Was 'the bloop' a glacier quake? Please tell me it was because I'm terrified of the ocean as is.

What is the bloop?

Celeste: I don't know what the bloop is…

Aside: Alisson B… or rather, Alisson B's girlfriend, also asked this question and we had no idea - no idea - what the bloop they were talking about. But Celeste emailed me right after the interview later that night with a link. Apparently, in 1997 oceanographers recorded the loudest noise ever heard under the sea! [*underwater white noise, then a subtle 'bloop', like a bubble moving through water*]

A bloop! A sound like a walrus gently farting in a bathtub. But so loud that NOAA (the National Oceanic and Atmospheric Administration) says on their site, "Was the bloop from secret underwater military exercises? Ship engines? Fishing boat winches? Giant squids? Whales? Or some sea creature unknown to science?" For years and years, until 2005, all these conspiracy theories about The Bloop swirled around. No one knew what The Bloop was. People were losing their minds. WHAT IS THIS BLOOP?

Turns out, it's the sound of an ice quake, and the chunk calving off into the ocean. Bloop. Like an ice cube in your lemonade. And NOAA also mentioned that we can expect more and more future bloops.

Alie: Hollis, great question: What causes glaciers to be so blue?

Celeste: Oh, this is a great question. If you have not seen how blue a glacier is, you need to, like, Google Image search glacier ice. Especially search for glacier ice caves because that gets you the blue really good.

Glaciers are blue for the same reason the ocean is blue. It's *not* the same reason as the sky is blue. The sky is blue because of scattering of light. Large quantities of water and large quantities of ice are blue because water molecules, like, a bond stretch in there, can absorb light but it gets absorbed on the red end of the spectrum. As light is coming in, the red just gets absorbed out, and so all you're left with is the blues, and they're

very, very lovely. My favorite color in the world is looking down a glacier crevasse and just seeing… It is so, *so,* SO…. It's the bluest blue.

Alie: [*squeals*] I've got to ask someone at Pantone what color number that is.

Aside: *Of course* I looked up ice caves, which are surreal and gorgeous caverns of shimmering surfaces and these deep, moody, blue tones. And then I went to Pantone and I typed in 'Glacier' and they have a color called Glacier. But it was, like, kind of minty green… They have a color called Arctic, but that was just, kind of, a straight vintage army color. They also had an Iceberg Green, but that was, again, like a powdery olive. And I'm looking at these swatches and the closest I could find to the color of ice caves was this, sadly, unnamed chip known only as 2985C. And it kind of captured that cool aqua of an ice crevasse.

And then I was like, "Maybe they have a color called Ice Crevasse." They do not have a color called Ice Crevasse. Then I realized that the 2020 Pantone Color of the Year is… Ready for this? Classic Blue. Just… Straight up blue. Which, I will say, if you compare it to those dim ice caves, is pretty spot-on. So, that's magic.

Alie: Jennifer Tran wants to know: Are there Ice-canos? Like an icy volcano?

Celeste: There are a lot of places where there are volcanos with glaciers on them, on Earth, and potentially on other planets… There is what's called Cryovolcanism.

Alie: WHAT.

Celeste: So, places like icy moons, or outer planets, places like Enceladus and Europa maybe have cryovolcanism, which is just like a volcano but it's solid and liquid water instead of solid and liquid rock.

Alie: No way!

Celeste: Yeah.

Alie: So when it spouts out of there, is that cold? Is it hot? Is it like a dome full of ice and then water shooting out of the top?

Celeste: Yeah! It'll refreeze pretty quickly because it's cold out there in the outer solar system, but yeah, it's a volcano. It's ice and water, and just like lava shoots out of a volcano and then rapidly 'freezes' into rock, water would shoot out of a cryovolcano and then rapidly freeze back into ice.

Alie: What is life! That is so bananas! Charlotte Hunter, first-time question asker, says: Native traditions in Alaska and elsewhere possess rich mythologies regarding geological events. Do you know of any that focus on glacier quakes?

Celeste: I'm not exactly sure. I do know that one interesting bit of indigenous knowledge and seismology is the fact that the Pacific Northwest can potentially have very large earthquakes that can cause tsunamis. When Westerners started interacting with indigenous peoples in the Pacific Northwest, they heard in those people's oral traditions about stories of the ground shaking and then a giant wave coming. And they thought, "Oh, look at their silly creation myths." But that was actually just real oral history of past earthquakes and tsunamis happening.

So that's one thing that folks are trying to do in geoscience, is making sure that we're not doing our geoscience from a colonialist perspective. So I don't know specifically, I do know that glacier myths feature in a lot of cultures native to areas like southeast Alaska where I work.

Aside: I read up on this a little, and there *is* a First Nations idea of sentient forms of nature, and glaciers in some indigenous accounts are depicted as powerful but a little catty, seeking some chilly revenge for human offenses. And there are adages of not frying anything with grease on a glacier because the noise of, like, crackling bacon or simmering oil is thought to mimic or even mock a glacier quake, possibly causing an outburst flood, which is pretty bitchy and very dangerous. So, tread lightly if you do tread at all.

Alie: Amber-Leigh Noelle, first-time question asker, asked: Why on Earth are we still allowing people to commercially visit glaciers? Is it as bad for them as I think it is? And Amber-Leigh lives close to Jasper National Park, and that has a beautiful Icefields Parkway, and gets really sad when they notice how far it's receded in the last ten years. Should tourism on glaciers be allowed? How do you feel about it?

Celeste: Well, it is really cool that people can go experience a glacier because, as someone who has worked on a glacier, experiencing them and physically being there is something that's so cool. But yeah, I understand the reservations about that since it is a little bit of a delicate landscape. But a lot of the… When glaciers recede it's because of larger scaler climate effects rather than individual actions local to that area, generally.

So, maybe less tourism because that's less of a carbon footprint, but as far as going to a national park and admiring the glaciers they have there, that's pretty cool. If you can do that in a low-carbon way, then I highly encourage you to because there's a lot you can learn, and it makes you value those environments more, so that way you are, maybe, a little bit more motivated to help create a world where our climate is a little bit safer in the future.

Alie: So, just some people breathing on a glacier is not what is causing glacier recession.

Celeste: Yeah. The glacier is receding because of larger-scale changes than people at the National Park Visitor's Center.

Alie: So, Amber-Leigh Noelle, you can breathe a little easier on that. That's really interesting.

Aside: We're all concerned about glaciers. I get it. And so does a patron named Rot, who simply commented: F in the chat for all the melting glaciers. :(

Krystyna Dallaire asked: Is there any way to reduce the pace at which glaciers are melting, or are we screwed because we've passed some kind of tipping point?

Celeste: I do know that there is some, kind of, wild geoengineering happening to try to preserve glaciers. I think there's a spot in the Alps where a glacier has been melting, and that melts out, for example, dirt and debris on the surface, and that's a darker color than the ice, so it sucks up more heat and it melts faster. So they are essentially, part of the time, covering it with, like, a giant white tarp, like a giant white blanket, to help keep it cooler. Yeah, there is some radical geoengineering that people are trying to do to protect glaciers that are currently being impacted by climate change.

Aside: One example is an 'ice stupa' which is this conical, artificial mini glacier formed by spouting water up in the air and having it freeze into a big ice cream cone, or stupa, which is a temple shape. And as it melts in the Spring the water can be used by the communities. This was invented by Indian engineer and genius Sonam Wangchuk, who first implemented this in 2014.

Just as an aside, he also suggests starting your day with a cold shower because it makes everything else in your day seem comparatively easy. And it also saves a lot of energy, so someone else please do this for a week and report back. Just the thought of this makes my butt wince.

Alie: A few people asked about things that are hiding in the ice as they melt. Ruby Oestreich asked: How screwed are we by all those bugs hiding in the ice as they melt? Like, are there bacteria that are going to pop up and be like, "Surprise!"?

Celeste: You probably don't have a ton to worry about with, like, glacier ice. But permafrost, stuff melting out of permafrost, which is frozen soil, like when the near-surface ground is totally frozen year-round, some funky, *funky* stuff can freeze into that, I know. So I do think there's some concerns about, you know, what kind of bacteria or viruses might be in that. So permafrost melting might release some funky things, but probably not from just straight glacier ice.

Alie: Okay. Haley Vandewall has a really scientific question. Wants to know what you do about dry skin and cold hands? Asking from Pennsylvania in February. [*laughs*]

Celeste: [*laughs*] So, where I am for my field work, in southeast Alaska, we're actually pretty lucky because I'm there in the summers and it's surprisingly pleasant out there. Sometimes it's a little too pleasant and makes me concerned about climate change. So, where I am, luckily, it's quite pleasant. But I know when people are going to even colder places like Greenland and Antarctica, they do take bundling up very seriously. Making sure that everybody is staying safe and healthy in very cold conditions is serious business for folks working in any outdoor environment.

Alie: Yeah! What kind of moisturizer? What kind of hand cream do you that?

Celeste: [*laughs*] I definitely bring Vaseline for my lips because I get super dry lips. But just regular ol' drugstore lotion gets me in the summers in Alaska, so I'm okay.

Alie: Several people asked if you have a favorite glacier.

Celeste: I think my favorite glacier is the first glacier that I did fieldwork on, which his Lemon Creek Glacier in Southeast Alaska. It's just outside of Juno. But I've also done work on Taku Glacier, so Taku Glacier has my heart as well.

Aside: Taku Glacier, by the way, is a 36-mile long boy in Alaska.

Alie: What's the shittiest thing about being a cryoseismologist?

Celeste: I thought about this because I know you ask, like, what's the best and what's the worst.

Alie: Yeah! [*laughs*]

Celeste: And I came up with, like… They're sort of the same thing as both the best and the worst. Fieldwork is kind of the best and the worst. It's the best because it's, like, really amazing to be out in such a cool environment. It's phenomenal. But also it kind of sucks because

it's a high-pressure situation in some ways. You have to really make sure that you're getting everything done exactly right, because there's not really take-backs in the field, because it costs a lot to get you there, and you're trying to do everything, you know, live. [*"We'll do it Live!"*]

And it's also remote, so if something breaks and you don't have the exact size of screwdriver to fix it, then you've just got to figure it out. It's really cool, but it's also stressful in some ways. You really have to make sure you get it right. So that's the best and the worst. The best is existing in those environments, and the worst is the pressure that goes with that.

Alie: What do you love the most about seismology?

Celeste: The thing I love most about seismology in general is that people are very interested in it. When people find out I'm a seismologist they want to tell me about an earthquake they felt, and I love hearing those stories. It's really cool to hear the ways that different people have experienced earthquakes. They tell me about the one they felt when they were a kid. They'll tell me about the one they felt a couple months ago or something. It's cool to hear people's stories.

And it's also cool to, like, help bust some myths about seismology and remind people that, no, nobody can be predicting earthquakes. No there's no such thing as earthquake weather. No, we don't know when the next one will be and we're hiding it. There's all kinds of myths to bust about seismology, so I really like that it's a science that a lot of people are interested in just in general.

Aside: Oh, and what is the best gear to have? Is it earmuffs? A ski mask? A cape?

Celeste: The important thing is the waterproof pants. It's THE essential field item. Without waterproof pants, you are sunk. [*Alie laughing*] A good jacket and the waterproof pants are the *real* game changers.

Alie: This is amazing. Thank you so much for doing this.

Celeste: Yeah, thanks for having me.

So ask smart people your stupidest questions. I swear I have done this thousands of times, no one has thrown a shoe at me yet. It's glorious. To learn more about Celeste Labedz's work you can follow her on Twitter or Instagram, @CelesteLabedz. We are @ologies on Twitter and Instagram. Please do befriend us. I'm on both @AlieWard. We have an Ologies Podcast Facebook group full of very cool human people sharing weird science stories. Thank you, Erin Talbert, for adminning that. And for hats, and pins, and totes, and such, hit up OlogiesMerch.com, which is adminned by Shannon Feltus and Boni Dutch of the podcast *You Are That*. And assistant editing was done by Jarrett Sleeper of the podcast *My Good Bad Brain*. And thank you to the rock that is Steven Ray Morris, who hosts a dinosaur/Laura Dern podcast *See Jurassic Right*, and a kitty podcast, *The Purrrcast.* Nick Thorburn of the band Islands wrote and performed the theme song.

And if you listen to the end, you know that I reward and burden you with a secret from my soul. And this week's secret is that I'm in Chicago, it's very cold, and I'm here for Jarrett's grandfather's memorial service. And we were celebrating his life by gathering in his favorite local watering hole, and I was offered a shot of Jeppson's Malort, which if you are from Chicago you know this is a local

tonic that Chicagoans muster through with pride. And we had a shot of Malort in his honor, and it tasted kind of like herbs and vanilla going down, and then it had this aftertaste, like a bitter aftertaste. I was trying to figure out what it was, like grapefruit or something? And then I realized what it reminded me of, and it was, um, bile.

Anyway, to Chicago. I also ate a hotdog. And I'm so sorry, but I did put ketchup on it. I'm recording this under a desk at an Airbnb because I want to get it to you ASAP. Okay, Berbye.

[*outro music*]

[*clip of Arnold Schwarzenegger as Freeze from Batman and Robin, 1997: "What killed the Dinosaurs? The Ice Age!"*]

Transcribed by

Your bee-and-fungi obsessed pal Aska, who stands with Wet'suwet'en land protectors in Canada

Emily Staufer

Emily White

Some links you may find of use:

"Day After Tomorrow" clip

Bill O'Reilly would like do it live, please

"Circle of Life"

"Chasing Ice" calving event

Where **are** glaciers?

What is sea ice?

"Chasing Ice" Trailer

Iceland's glacier funeral

More on Iceland's funeral

Frost quakes!

Cyroseisim frequencies

Mapping global glaciers

Sad/eerie things found on glaciers

More things found in glaciers

First Greenland impact crater

Second Greenland Impact crater

Hiawatha Glacier

Zee “Bloop”

So cool, it’ll put you in a stupa

Take a freezing shower every day

For comments and inquires on this or other transcripts, please contact OlogiteEmily@gmail.com