Season 4, Episode 1

Climate Modeling: Compelling research questions and human concerns

SPEAKERS
Emily de Jong, Tapio Schneider, Sarah Webb

Sarah Webb 00:00
Welcome to season four of Science in Parallel, a podcast about people and projects in computational science. I'm your host, Sarah Webb. And this season, I'll be talking with guests about creativity, how it fuels both their computational research and their daily lives. We'll start off with an episode about climate modeling and my conversation with Emily de Jong and Tapio Schneider, who are both at the California Institute of Technology, or Caltech. Emily is a graduate student in mechanical engineering, and Tapio is a Professor of Environmental Science and engineering. And he's Emily's PhD advisor. Emily's research is supported by a Department of Energy Computational Science Graduate Fellowship.

Sarah Webb 00:43
I spoke with Tapio and Emily in July at that program's annual meeting in Washington, DC, where Tapio gave a keynote talk about the Climate Modeling Alliance and their work to build a new, more accurate earth system model that can simulate uncertain processes such as those within clouds. In this conversation, Emily and Tapio describe how both the science and societal impact of climate modeling motivate them, how outdoor activities and music shape their perspectives and how they view creativity both inside and outside the lab.

Sarah Webb 01:18
Later in the episode Tapio shares his experience as a science advisor to the ClimateMusic Project, an artists' collaboration that's producing music and video pieces that explore climate change and solutions to the climate crisis. We'll lead into our conversation with one of the pieces that Tapio consulted on: a violin concerto by Theodore Wiprud. This computer-generated clip comes from a section of the piece looking at potentially virtuous changes that could address the crisis.

01:56
[swirling orchestral music]

Sarah Webb 02:01
To start, I want to get some context for your interest in climate: how climate change got on each of your radars and how that became a problem that you decided that you wanted to work on.

Emily de Jong 02:16
I came into climate science after doing some internships in the oil industry, sort of by accident. When I came to Caltech, I intended to work in some sort of modeling of fluids that was relevant to energy and the environment. And I had the privilege of meeting Tapio during that first year at Caltech. And it seemed like a really unique opportunity to work on earth system modeling directly, and specifically this question of aerosols and cloud particles in the atmosphere, which was not a field of science that I had been exposed to prior to coming. I started in chemical engineering, applied to mechanical engineering at Caltech and found myself working in environmental science and engineering. So it was all sort of an opportunistic set of choices that got me there. But it seemed like an opportunity that I couldn't and shouldn't pass up.

Sarah Webb 03:08
What about you, Tapio?

Tapio Schneider 03:09
There's maybe two stories, one, so the scientific story you put in a CV, and then there's the life story. I think the scientific story is my background is in physics and math. I always loved physics of everyday life. And when I started out in physics, that's what I loved learning. And why is the sky blue and, say, the quantum mechanics changed all our lives gave us all these electronics we have. Physics were at the cutting edge when I was a student in the 90s. It was either at absolute zero temperatures or at very high energies. And I was looking for physics at the energy of sunlight, day-to-day life. And so I scientifically thought climate, atmosphere, oceans is an interesting area to study.

Tapio Schneider 03:51
I was an exchange student at the University of Washington. It has a very good atmospheric science department, oceanography department, where I get to know some people and get to know the field a bit. I applied to grad school in the climate sciences, not quite knowing, I think, what I was getting into at that point. It appealed that it was a young field. Or I felt as a young scientist-- the same is true for Emily now-- you can make a contribution that lasts. And, you know, I stayed evidently. It mattered to me, too, that it's an area of human concern. I was concerned about climate change at the time. I used to be a competitive cross-country skier, and ski races kept being postponed and moved. And I started to wonder why that was and became interested in global warming, climate change as a high school student. It was in the 80s. And that was a factor as well, but maybe not the only factor of how I got into the climate sciences.

Emily de Jong 04:41
Can I just say, it's been a very happy realization of what Tapio mentioned that it is a young field and that you can make contributions as a scientist in the field. And it's also a very supportive field, which I did not know going into it. But I think that the earth sciences have been especially friendly and welcoming even to somebody without that background inherently, even compared with fields like more traditional fluid mechanics.

Tapio Schneider 05:06

Yeah, it's very much an immigrant field-- immigrants from other scientific disciplines. Most of us have a history coming somewhere from the sidelines. It's very open to new people coming in.

Sarah Webb 05:16
And I assume part of that is that interdisciplinarity of it, there's so much information and so much science that goes into understanding climate, right, can you talk about how you started thinking about what you could bring to the field?

Emily de Jong 05:31
I came into the field thinking, Okay, this isn't too different from what I intended to study. It's still particles in some sort of fluid flow. And that's not so different from studying contaminants in groundwater or solid particles in combustion, for instance. So the physics regime is different, but the underlying physics are similar. But there's a lot of terminology in the earth sciences that I had to get familiar with to the extent that I created my own dictionary of acronyms and words that I kept having to refer back to in my first year, because I had never heard of this liquid water path, or ice water path, or any of these things that are specific to discussing fluids on a rotating plane, for instance.

Tapio Schneider 06:14
I think the acronyms can be really a hindrance to entrance. I remember sitting in one of my first atmospheric science seminars at the University of Washington and hearing someone talk about SST for a long time without knowing what this person was talking about, which is sea surface temperature. After a time you assimilate and you learn. I think what makes the field appealing to me is I always liked physics of complex systems, and complex systems where many different things come together. I think there was always my physics: More Is Different, the famous title of an essay, and bringing together ideas from different disciplines maths and physics and computing. I think it was always the kind of science that appealed to me, and still does. I think what I still enjoy about the field is how much I still learn every day because the system is so complex. The land biosphere is one example. I didn't know very much before about it, and I continue to learn. It's just really fun to bring these ideas together toward a better understanding of how this very complex system operates.

Sarah Webb 07:17
Related to the complexity, I want to ask you each about computing. It's the chicken egg question: Which came first, the climate or the computing,

Tapio Schneider 07:24
Computing was definitely first for me. So I grew up in the age of home computers becoming available in the 80s. And I had one of those and was absolutely fascinated by what you can do with computers. In fact, I sold my first software package when I was 14 or so, participated in computer science competitions as a teenager and the like. I was very immersed in the computing world. I had a research assistantship as an undergraduate in a biophysics group and building software for biophysics lab that introduced me to what at the time was higher performance computing. It's, of course, laughably nonperformant compared with what we have now. The computers we had were less powerful than the watches most people have on their wrists now. But it introduced me, for example, also to the first generation of neural networks at the time, and climate came later. And I worked more on the theory

side and climate for a while. But what I do now is very much bringing the computing back strongly. And I like that as well.

Sarah Webb 08:25
Emily, what about you?

Emily de Jong 08:26
Computing also came first for me, in part because the computer science department has such a huge presence at my undergraduate institution, Princeton. I think it's the largest or one of the largest departments by far. So when I got there, I thought, yeah, I'll take some computer science, and I liked it well enough, not well enough to make it my major. And my first research project as an undergraduate, I really dove off the deep end. I reached out to Professor Emily Carter at Princeton, and people in molecular dynamics very far from what I do now might be familiar with her. So all of a sudden, I was thrust into this world of learning how to use the terminal, learning how to run and aggregate data on a high performance computing system. And I would say, I have retained those skills. The skills of orbital free density functional theory have long since escaped me. But that was definitely my first exposure to high performance computing. And since then, I've always been interested in more of the theory that goes into how you actually design systems of physical equations to function on those HPC processes.

Sarah Webb 09:33
Let's talk about this big challenge of climate. And, Tapio, can you talk about when you entered the field of climate where we were and how you've approached your career and the kind of challenges that you decided to take on along the way?

Tapio Schneider 09:48
So I mentioned I was working more on a theoretical science and climate. But theory is not just paper and pencil in our case. Theory always means that you use simulations as experiments. The atmospheric sciences are really the first computational science where we use computer experiments in lieu of, the actual experiments we would all love to do. But it's hard to build an Earth at lab scale, basically can't be done to reduce all the processes you want to capture to something even built in a laboratory. So instead, we use simulations. These simulations are used for atmospheric, it's called general circulation models, so global atmosphere models that are simplifying things like precipitation and cloud processes. And they use them to study properties of atmospheric turbulence, what's called the macro turbulence or large-scale turbulence driven by the gradient in solar heating between the equator and the poles. I used computers primarily to generate large numbers of experiments with which I could test theories from which I could develop theories. And doing things like what you would do as an experimental scientist: vary parameters over wide ranges, like Earth's rotation rate, the size of the planet, insulation properties, and often vary them wildly, beyond anything that has occurred on Earth, or even on other planets potentially, to elucidate fundamental properties of turbulence.

Sarah Webb 11:10
So, Emily, it sounds like these kinds of physical questions, were things you were interested in. As you've been thinking about this as a graduate student, what problems have you grabbed onto? What are you most excited about tackling?

Tapio Schneider 11:10
That's how I used computing. I was very much a user of models at the time. In that I took, in that case, a model from GFDL, and NOAA lab and Princeton, where I was doing my grad school, and stripped it down to the experimental device that I wanted to work on. But I wasn't developing the model myself. So that's something that came more recently. And that-- climate models are imperfect. That's not a new realization. But maybe a decade or so ago, I thought in academic circles, people often lament that climate models are not as good as they could be. But we should do something about it, we have academic freedom, we can work on, essentially whatever we like. And the biggest problem in climate prediction are small-scale processes, for example, that control clouds. I decided to work on those types of processes. Before I was working on turbulence and thousands-of-kilometers scales, and then started to work on scales of meters to kilometers or so. And so first, again, to understand properties of the small-scale dynamics, but now also to build new models that captured the small-scale dynamics better. So now, with Emily and many others in our group, we're actually building all new software or new models ourselves.

Emily de Jong 12:40
So when I first came to Tapio and expressed an interest in working in his group, he asked what kind of problems I like to work on. And I said, I like building things. I like building models and thinking about the math that goes into them. So I was almost more motivated by that sort of hands-on application than by the fundamental science questions themselves, in part because I didn't know what they were in this field. And so the question that I eventually latched onto is one about cloud microphysics, which if you ask many people in the climate sciences, it's something that they wouldn't touch with a 10-foot pole, because it's messy and difficult and problematic. In fact, somebody said exactly that, to me at a climate dynamics workshop in Norway last year: They were glad somebody else was working on it.

Emily de Jong 13:27
And there's a lot of complexity that goes into cloud microphysics. It's all of these droplets in the atmosphere that we can't directly resolve or model. And yet, somehow, we need to understand what's going on with them. If we want to understand how clouds will respond to global warming, how changes in aerosol concentration, change the clouds, and that feeds back onto the planet, for instance. And I found myself diving very, very deep into one question about cloud microphysics, which is, when do cloud droplets become rain droplets? And if you think about it, logically, it has a very simple answer. It's at the moment that they fall out of the sky. But that's not necessarily what the models themselves are keeping track of. And this is sort of one of the canonical and long-unsolved problems in cloud microphysics because it's something where we have to create artificial parameterizations. And that introduces a lot of uncertainty into these models. So the problem I've taken a deep dive on in quite a bit of my research now is this question of how we can keep track of cloud droplets or rain droplets, for instance, all these hydro-meteors in the sky, keep track of their size, keep track of how they interact, how they collide, and coalesce with each other, and how that leads to then precipitation. And that requires thinking a little bit more creatively about what quantities we actually keep track of in our climate systems or in our large eddy or weather models in order to accurately model those physics.

Sarah Webb 14:56

I think we're in a very interesting space with any computational science field where you would love to have computers that could do more than they do. I want to get a sense from each of you about the interplay between computers and science, and how the power of the computer drives the question that you're able to answer, and how you think about how to make progress when you're working at the edge of what your tools can do.

Emily de Jong 15:22
Well, I think it's pretty clear with cloud microphysics that limitations in computational ability are the reason that I am able to study what I do. If we had infinite computing power, we would resolve individual cloud droplets in maybe a Monte Carlo simulation, for instance, and we would have, you know, 10^{15} droplets per, I don't know, cubic centimeter. That's obviously infeasible. And so that is sort of the driving force, the fact that we don't have that kind of computational power and won't for the foreseeable future, is the reason why we have to come up with approximations of the physics that take place between cloud droplets. Not because we don't understand them at all, but because our understanding cannot be realistically modelled on existing computational platforms. So that then drives the question in mathematics, in parametric and structural uncertainties of the model, also, in observations in trying to come up with data to actually learn and reduce some of those uncertainties from.

Tapio Schneider 16:31
I like the perspective that because of finite computational capacity, scientists will remain necessary for a long time in this field. I agree. I think the role of computing has always been large in the climate sciences. In fact, John von Neumann, who designed the modern computer architecture at the Institute for Advanced Study in Princeton at the time, realized right after the Second World War, that the atmosphere is an interesting computational challenge. And so the ENIAC, the first computer, first used for artillery calculations. The first scientific problems that was used for was weather prediction, the atmospheric simulations. And John von Neumann started a weather prediction effort, hired a number of, at the time, young people who've been some ways became the founders of the modern atmospheric sciences, Jule Charney and Norm Phillips.

Tapio Schneider 17:24
And so the atmospheric sciences are the first computational science. Since 1947 people have used computers to study the atmosphere numerically. And the climate sciences have always been at the forefront of computing using the biggest computers available at any given times. Whatever the DOE is building, climate simulations are being run on it. And the reason is what Emily said that, in principle, it would be nice if he could resolve more. But there is just such a vast range of scales, it's completely infeasible. So the atmospheric turbulence alone has 10^{27} spatial degrees of freedom, no way to retain that in memory. And that's just the turbulence. And so it's not even covering what Emily talked about: the microphysics that happens on yet smaller scales. So the biggest computers we can get, we'll fill up. And it will not be enough to simulate everything that matters down from cloud droplets, aerosols to planetary scale circulations, and hence, scientists, engineers who augment the powers of computers will remain essential.

[Several seconds of music]

Sarah Webb 18:35
What are your passions and interests outside of science? How does that help fuel you when you are focusing on the problems at hand?

Emily de Jong 18:45
These days, I spend a lot of time in the outdoors. And I feel very grateful that Tapio is an advisor who encourages and supports that, especially after moving to California where the weather is somehow much better than that of New Jersey, believe it or not. I found myself spending a lot of time outside with my original hobby of cycling, and also taking up new things like rock climbing and mountaineering. And I definitely now have the opportunity to think about what's going on in the atmosphere and in clouds. In particular, when I'm out there, I don't want to say that that's 100% what I'm doing out in the field-- I like to describe my bike rides as observational fieldwork. But that's truthfully, not actually the goal of them. But there's something really fascinating about waking up early in the morning, bicycling up a small mountain outside of Pasadena, and all of a sudden emerging on top of this stratocumulus layer. So you're looking out, and you see just a layer of clouds as far as the eye can see. And actually having some understanding of what's going on there, why that happens, what's going to happen to that cloud as the day goes on that otherwise I might have been completely unaware of. Maybe just seeing the cloud was like an impediment to my visibility of the ocean or other things or something inconvenient. And so it's definitely changed my perspective a little bit. It's even more important if I think about going on like a big mountaineering expedition, for instance, and thinking about how important weather is for the success of climbing a big mountain. That's something that I used to think of as, oh, it's a completely random phenomenon. It just happens, and you get lucky or you don't. But it almost gives me a greater sense of control to have an understanding of what's going on and why, even if it doesn't actually help me get off the mountain anymore safely in the end.

Tapio Schneider 18:55
Safety is important. As I mentioned, I used to be competitive cross-country skier. And that's still my favorite form of locomotion. So whenever I can, I try to get on cross-country skis, or sometimes roller skis, and I have two children. They are 11 and 13. So that's obviously a large part of my life. They are all very active of being outdoors, too. So this is something we all do together. One of my sons, especially, is a very avid snowboarder, and the other skis. I did get into the field and part because of disappearing snow, where I grew up, that's actually quite striking, you used to have something like 120 days of snow on the ground for a year, and it's reduced by almost a factor of two by now. And it's clear that soon there won't be any,

Sarah Webb 21:24
You're working on one of the grand challenges for the world right now. How does that affect you and affect your work?

Tapio Schneider 21:30
it lends a lot of urgency to the work. So I think in a lot of science problems as well, you have your career, and whether you figure it out this year, or in five years, it doesn't matter that much. Here it really matters. We really want rapid progress, because we need the information for all sorts of adaptation

decisions, infrastructure, planning decisions and the like. So it puts more time pressure on what we do than you usually have in science. It means that the scientific information you provide-- the value of that scientific information is in some ways, a decreasing function of time. At some point, the climate system will have shown us how it will change. And we want to predict that now not after the fact. So I think it's it is very motivating.

Tapio Schneider 22:13
At the same time, you know, we're scientists, engineers. I think I am, and I think most others in the group are, also very much motivated by these scientific problems in themselves, because they are just very interesting, apart from the urgency of solving them. And again, that's us working on complex problems, intriguing phenomena emerging on micro scales, from equations we can write down on a micro scale. And looking at the equations, you wouldn't be able to tell what beautiful things appear on the large scales. And I think that, to me, is also a motivating factor. But obviously right now, there is the practical motivation. And what I love about what we do is that it seems to be this perfect marriage of fundamental science and engineering, interesting problems with immediate applications and immediate societal needs for planning and the like. And, yeah, communication is always an important part of science and engineering. You want people to use what you do. And that's always important, of course, in our case, perhaps even more important because more people pay attention and the public debate on global warming. I've been following that now for more than 30 years and have been part of it to some extent. I would like our science to be a bit above the day-to-day of that. And while I'm happy to advise decision makers, for example, on scientific questions, it's the long view that taken that work as well.

Sarah Webb 23:50
Emily as somebody who's-- you're early-career, what has that been like for you coming in? Because you're coming into this field at a different discussion of climate change. I mean, we are seeing the impacts of it in very real ways. People talk about it in a different way than they did 20, 25 years ago. What does that mean for you?

Emily de Jong 24:06
It's interesting, you say people talk about it differently. Because I grew up outside of Fort Worth, Texas, where I think maybe the discussion on climate change is 10 years behind where it might be elsewhere in the United States. Maybe partly as a result of that it wasn't something that was high on my radar in terms of actual understanding of the fundamental questions and problems other than knowing that it was a hot and controversial topic until I was maybe partway through college actually. And so for me, the fundamental question was always this question of energy availability and security. And that was, in part, motivated by an inherent understanding that that will need to change partly as a result of global warming. So that was one of the underlying motivations, but the question I always found interesting, especially in college, was: Where are we going to get our energy from as people continue to demand more and more of it both in the United States and also elsewhere in the world?

Emily de Jong 25:08
And so that was initially what motivated some of my research, both in the oil industry and also at Princeton as an undergraduate. And when I came to Caltech, that was also part of my inherent motivation. And so it was completely new for me to be able to think about the questions. Well, what

actually causes these changes under global warming, or under co2 or aerosol emissions in particular, that lead to these upcoming challenges? And so in some ways, I actually feel empowered now in thinking about these questions, empowered by having a more clear understanding of what those changes may or may not look like. And-- I don't know-- that feels good. It feels much better to, to feel empowered to solve problems than it does to feel like the work that I do leads to negative conclusions or negative outcomes for the planet. And I think it's also much easier to talk to people, especially people where I'm from, for instance, in terms of solutions and specific challenges, as opposed to what is seen as a controversial national topic.

Tapio Schneider 26:09
That's the thing that has most changed over my career in this field that now you can talk about solutions and they are on the horizon. You can see what a solution looks like. When I started working in the field and started worrying about global warming, there was no clear solution. I mean, the problem I would say was, to me just as acute in the 90s, as it is now, the big picture predictions haven't changed dramatically. So it was foreseeable what will happen, and it has happened. But in the 1990s, it was difficult to see how we solve this. I was in grad school. I wasn't flying to conferences. I was taking trains and buses all over the US and such things. But that was not a scalable solution to the problem. And what's really interesting now is that solar power has gotten so much cheaper, dropped by almost a factor of 10, in the last 10+ years in cost. Renewable technologies have become cost-competitive with fossil fuels and, in fact, are cheaper than fossil fuels for new installations in many places. That solution seems to be on the horizon. There is no easy solution. These are still hard problems, and there are still many engineering, regulatory, legislative issues to be solved. But one can see how it can be done now, and that was harder 30 years ago.

Sarah Webb 27:27
So Tapia I wanted to ask you a bit about the ClimateMusic Project. How do you illustrate to people what is going on in this very complex system that is our home on our planet?

Tapio Schneider 27:39
The ClimateMusic project is a project that pairs musicians, composers, songwriters and the like with climate scientists to create music that addresses global warming and to some degree solutions as well. I feel it is important also, to make clear, this is not all doom and gloom, there is a way out. And the climate music project to me has just been a source of joy and fun. I mean.

Sarah Webb 28:03
How did that get started?

Tapio Schneider 28:05
The people came to me in that case, who had started a project. And then we've had, for example, there's an ongoing project with a composer writing a contract concerto and that thematizes global warming. We had sessions with songwriters are just not the thing that we have in our day to day working life and Emily and Amy No one breaks up the guitar and breaks out into song. And so here we are sitting with a bunch of songwriters and you give us an idea for a song and they take out the guitar and say, How about this:

28:35
[The song "I Wanna Be Cool" fades in] *I wanna be cool isn't a joke—to walk in the woods without all the smoke. I love to swim but not in a flood. You can't grow a crop down in the mud.*

Tapio Schneider 28:59
Coming up with lyrics together. And that's really enjoyable and also enjoyable to see how what these talented musicians make out of it can connect with people on a very different level.

Sarah Webb 29:11
How much do you learn about how people connect with it? Are there concerts? Or do you get feedback in some way?

Tapio Schneider 29:16
You know, there are concerts. There are records released now by these songwriters with whom we're working. Some coming out soon. Yeah.

Sarah Webb 29:23
That's really awesome. It sounds like you play a little bit.

Tapio Schneider 29:25
I used to play clarinet primarily in saxophone in mostly high school and a bit beyond. I always thought of myself as a poor musician. And it turns out there was playing this people who became professional musicians, so they were very good and, relatively, I was not very good. But yeah, I don't play much anymore myself.

Emily de Jong 29:43
Tapio, do you have any bassoonists on your roster of climate musicians these days?

Tapio Schneider 29:48
People directly working with no, but there are their orchestral pieces, including bassoon So, if you're interested, yeah, maybe there's a concert or that you can get involved in one day.

Emily de Jong 30:00
That'd be very cool. Yeah.

Sarah Webb 30:03
So So you're a bassoonist, Emily?

Emily de Jong 30:05
Yeah, I would say until I moved to California and got the outdoor bug, I was very focused on music as a kid, through high school, even in college. It took a backseat a little bit, in part because I was burned out from it. When I got to Caltech, rock climbing was infinitely more interesting at the time. I was actually not super familiar with Tapio's climate and music project. But I think he has an excellent point that

music can express and communicate the inherent emotions and aspects of being human that it's very easy to turn your ears off to when listening to somebody speak at you, or try to communicate through words. And it's been some time since I was able to really appreciate that aspect of music. So I'll be really interested to hear these albums when they come out.

Sarah Webb 30:58
Yeah, this is a really open-ended question, but I hope you're willing to play. For each of you, as scientists, as humans on the Earth, what does creativity mean to you?

Tapio Schneider 31:08
And I think to me, the main creative outlet is just the scientific work we're doing. I mean, to me, producing a good model that is excellent software, conceptually, first-in-class, that that is creativity. And this is I think, my main creative outlet is that work.

Tapio Schneider 31:25
In the age of big data, there is a latent fear sometimes expressed about loss of creativity for scientists. We are all going to be replaced by a black-box machine learning model that just learns all the signs from the data out there in the world. And I think that that fear is overblown. I think scientific, engineering creativity will remain absolutely essential for progress in this field, for several reasons. But one, one, really simple one is that the degrees of freedom and the climate system is just so vast, from cloud microphysics, to planetary circulations, to plants and the rest. There is, I think, no way to learn all of that from data. We have a lot of data, but not enough to learn all of that directly. And there is an important role still for scientific creativity that in the end is augmented with data, human creativity, I think the way we achieve progress, and the most rapid progress is by combining human creativity and say providing structure for physical models and alike with learning from data to allow us to make more rapid progress than the field has made over the past few decades.

Emily de Jong 32:40
I feel like creativity can play into work and research, but also into any sort of activity to life. And it's where to me, it's where you pull a tool out of the tool belt that's not built for the thing you're trying to hammer, and somehow it works anyways. So for instance, in modeling cloud microphysics, that could be pulling a numerical tool that hasn't been applied to cloud microphysics and trying to finagle it to work. In music, it's putting together sounds and harmonies that communicate some sort of emotion for reasons we don't really understand. Even in the outdoors, for instance, one of my favorite things is just sort of MacGyvering, whether it's in my backyard, or if I'm 100 feet up on a climbing wall and figure out some sort of random rope system to, I don't know, pull up a water bottle because I just decided right in that moment that I need a sip of water from the person who's 100 feet below me. Building a rope swing off of a canyon wall. Just that kind of fun sort of creativity is also something that I enjoy a lot.

Sarah Webb 33:43
And is there anything that we haven't talked about that you think is important to mention about either the field of climate modeling, where we're headed, basically, what have we missed?

Emily de Jong 33:55

I think it's worth just re emphasizing this idea that you don't need to be a classically trained climate scientist to play in that sphere. Tapio and I mentioned this earlier that a lot of people come into it from different backgrounds. And yet, I imagine that from the outside, it can still look like an intimidating field, particularly if you don't understand the jargon or feel insecure in your knowledge of earth systems. But I feel like that's partly where a lot of the ingenuity and creativity can come from is from people who haven't yet been exposed to the somewhat narrow set of computational tools that have been and are currently being applied to modeling the climate system. And bringing tools and ideas from other fields, I think is a way that innovation, hopefully can continue to happen in that field of climate science.

Sarah Webb 34:46
With that, I'm going to wrap up. Thank you, Tapio. Thank you, Emily. It was such a pleasure talking with you.

Tapio Schneider 34:53
Thank you, Sarah.

Emily de Jong 34:54
Thank you very much.

Sarah Webb 34:55
To learn more about Tapio Schneider, Emily de Jong and research and ideas mentioned in this episode, check out our show notes at science in parallel.org. We also have links and more information there about the ClimateMusic Project, related initiatives and the music and musicians featured in this episode. Special thanks to Stephan Crawford, founder and executive director of the Climate Music Project, and to Theodore Wiprud, Will Kimbrough and Brant Miller for allowing us to use clips from their work.

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We'll play out the episode with a bit more of the song "I Wanna Be Cool" by Will Kimbrough and Brant Miller that was featured earlier. The song is the center of a new climate action campaign called Be Cool! Which is a collaboration between the ClimateMusic Project and Music Declares Emergency.

35:51

[Song fades in.] *I wanna be cool. It's gotten too hot. I'm joining the movement to save what we've got. So every girl and every boy can live a good, long, happy life and find some joy. I wanna be cool- how about you? Together there's not one single thing that we couldn't do. Take care of the Earth and each other, too—working together, we all can be cool.*